# Compressed Air Magazine

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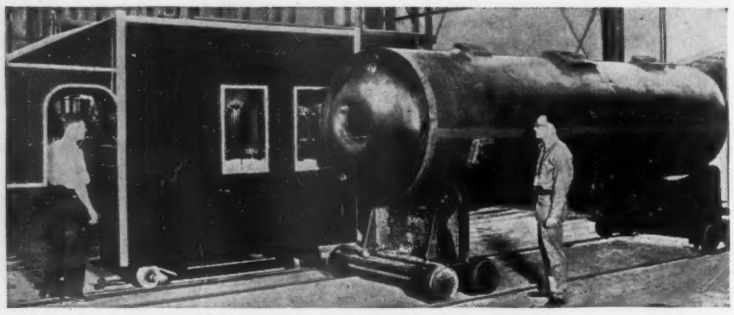
PHOTO NATIONAL DEVELOPMENT BUREAU, CANADA



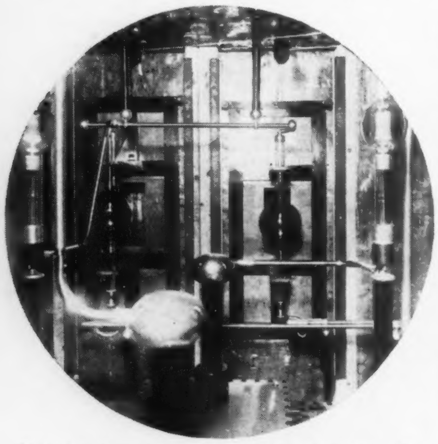
Two-tube x-ray machine of 250,000 volts capable of x-raying metal thicknesses up to 4 in.

# These Facilities

## *assure the Quality* of

## Walsh-Weidner Welded Drums

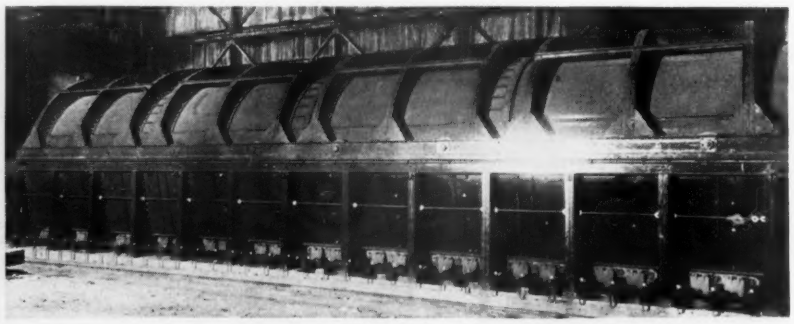
Annealing furnace. This furnace is specially designed for the stress relieving of boiler drums and pressure vessels. It will take a boiler drum larger than any built to date.



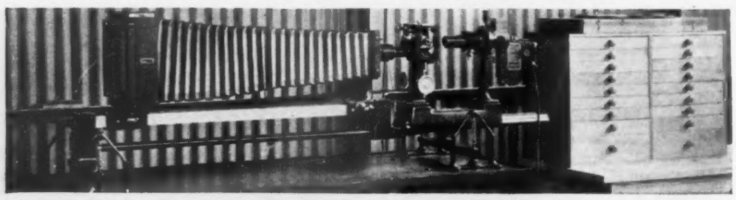
Interior view of x-ray machine showing the two x-ray tubes, Kenetron tube rectifiers and transformers.

**Our Hedges - Walsh - Weidner Shops at Chattanooga have every facility for the annealing and testing of fusion-welded boiler drums and pressure vessels. The welding technique used is the result of years of research and has been so perfected that it consistently produces a quality of work exceeding A.S.M.E. Code requirements. Recognition of the quality of Walsh-Weidner Welding is reflected in the fact that the volume of work produced in the first six months of 1932 is more than four times that produced during the entire year of 1931.**

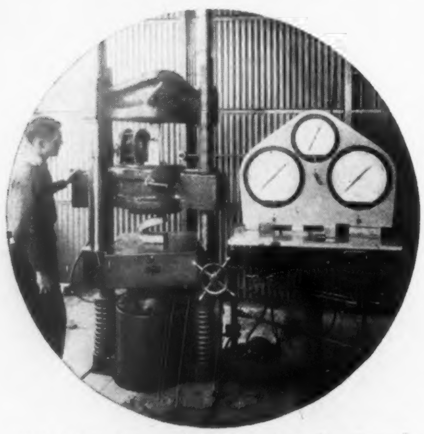
Machine for making Brinnell hardness test.



Annealing furnace with arched top in position.



Micro-photograph machine.



Machine for making tension, bend and compression tests.

# COMBUSTION ENGINEERING CORPORATION

**200 Madison Avenue** **New York**

# As It Seems To Us

### PROGRESS AT HOOVER DAM

ON NOVEMBER 13, a milestone of progress was reached at the Hoover Dam when the first of the four 50-foot-in-diameter diversion tunnels was placed in service. This marked the beginning of the end of the first stage of the work—that of by-passing the Colorado River through the canyon walls to permit excavating for the dam footings. Noteworthy speed of accomplishment has attended operations thus far, and Six Companies Incorporated are months ahead of their schedule. By the time melting snows at the headwaters of the Colorado send springtime floods down its course, the stream will have been completely and effectively pushed aside for the time being, and an ant hill of humanity will be digging anchorages for the great monolith of concrete that will serve to harness the energy of falling water to do man's bidding.

Once again we are impelled to reiterate the thought that the comparative ease and clock-like precision with which "impossible" things are being accomplished in Black Canyon fittingly exemplify the almost infinite capacity of the human brain to devise and to direct. Although mechanical contrivances and the muscles of men are performing the myriad menial tasks little by little, the marvelous and inspiring thing about it all is the advance planning which has enabled the working out of every last detail on paper with mathematical certainty and the providing of ways and means of coördinating the veritable maze of activities. The fact that every phase of the work is advancing smoothly and rapidly indicates the character of engineering talent that abides out there in the desert.

### UNCLE SAM—SHIPBUILDER

AMERICANS may well be proud of the merchant steamships that are being constructed in this country under the provisions of the Jones-White bill enacted by Congress in 1928. Our marine architects, engineers, and shipbuilders are proving that they can equal or better the best product of the Europeans, once they are accorded a satisfactory opportunity. Our leading article this month should make interesting reading, even for a landlubber. It tells the story of an outstanding achievement in marine power-plant design and construction. Our land engineers deserve some of the credit for this accomplishment. Advances in central-station practice during the past ten years have made it possible to build ships of such high thermal efficiency as the *Santa Rosa* and her sister boats. Great ingenuity had to be displayed, however, to accommodate those practices to the conditions that obtain aboard ship. We have referred to the feat as a capable bit of engineering "tailoring", and we know of no better way to describe it.

In its day, the Yankee clipper ship was the best vessel afloat. During the World War, Uncle Sam demonstrated that he could build transports faster than anyone ever dreamed they could be put together. These two eras are the high points in our maritime history. By and large, our commercial ships in foreign trade have not been up to the standards set by other world powers. Curiously enough, though, American-built ore carriers on the Great Lakes are of high efficiency.

The development of the steam engine started our maritime decline. England then had a great advantage in her primacy of machinery manufacture. Also, she had coal to fill her outgoing ships, which returned with food and raw materials. Between 1830 and 1898, the percentage of our foreign commerce that was moved in our own ships fell from 90 per cent to 9 per cent, and our Merchant Marine was in a sad plight.

But now, with Government coöperation to equalize the cost of construction as between America and Europe, our marine technicians are bending to their task with willing and intelligent hands and demonstrating in a convincing manner their ability to do a high-class job when they turn wholeheartedly to it.

The American public can do much to assist this laudable movement to create a merchant marine that requires no apologies if they will but patronize ships built in this country. For some inexplicable reason, the average traveler to Europe prefers a liner flying the flag of another nation. Even ardent champions of prohibition exhibit this tendency, so the character of liquid refreshments served aboard vessels of foreign registry cannot be held responsible. Here is a case where trading at home extends beyond the borders of our own country. A little peacetime patriotism would seem to be in order.

### THE EIFFEL CENTENARY

DECEMBER fifteenth marks the one hundredth anniversary of the birth of the late ALEXANDRE GUSTAVE EIFFEL, one of the greatest of French engineers. He is best known to most of us for the tower that bears his name and which still remains one of the foremost objects of interest in Paris after 43 years of existence.

The Eiffel Tower was erected for the exposition of 1889. At the time, its height of 984 feet far exceeded that of any other man-built structure, and it was not until the recent era of skyscraper competition in New York City that it lost that distinction. It was a daring piece of construction for that day, as it was 589 feet higher than St. Paul's Cathedral in London and 429 feet loftier than the Washington Monument, which were the previous record holders in the Old and New worlds.

Foundations for the tower were carried downward a maximum distance of nearly 50 feet by means of wrought-iron, open-bottom pneumatic caissons. The French had used compressed air before in water-bearing ground, but this was easily the greatest application of this expedient up to that time. It served to prove the efficacy of the method for heavy construction and was the forerunner of the present-day pneumatic caissons now in widespread use.

EIFFEL was at the height of his interesting career when the tower was started in January, 1887. He had previously built many large bridges in France and was the designer of the huge sluices used by the French during their unsuccessful efforts to dredge the Panama Canal.

### A BARN THAT GREW

TWO recent news items have served to direct attention to the research laboratory of General Electric Company at Schenectady. The first was the announcement that Dr. WILLIS RODNEY WHITNEY, organizer and for 32 years director of this renowned "House of Magic," had retired because of ill health. The second was the statement that a section of the laboratory will be exhibited at the Century of Progress Exposition in Chicago next year, at which time some of the more important of the discoveries and developments that have emanated from it will be shown to visitors.

In 1900, EDWIN H. RICE, Jr., then technical director of the company, established the research department, and Doctor WHITNEY was obtained from the Massachusetts Institute of Technology to head it. Available space was at a premium, so the laboratory was started in a portion of a barn in which the late CHARLES P. STEINMETZ had a workshop. A few months later, accommodations were found for it in one of the company buildings, and from that time on it grew apace.

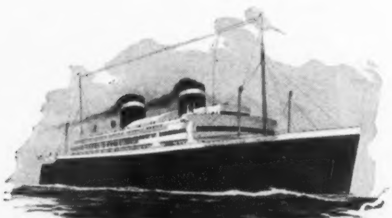
Out of this laboratory has come a long procession of achievements which have had an enduring effect upon mankind. For more than a dozen years past, the department has consisted of several hundred persons and has called for an outlay running into millions of dollars a year. Every dollar spent upon it, however, has probably been multiplied many times through the sale of the manufactured products it has made possible. More important, the laboratory has contributed immeasurably to the comfort and convenience of millions of persons.

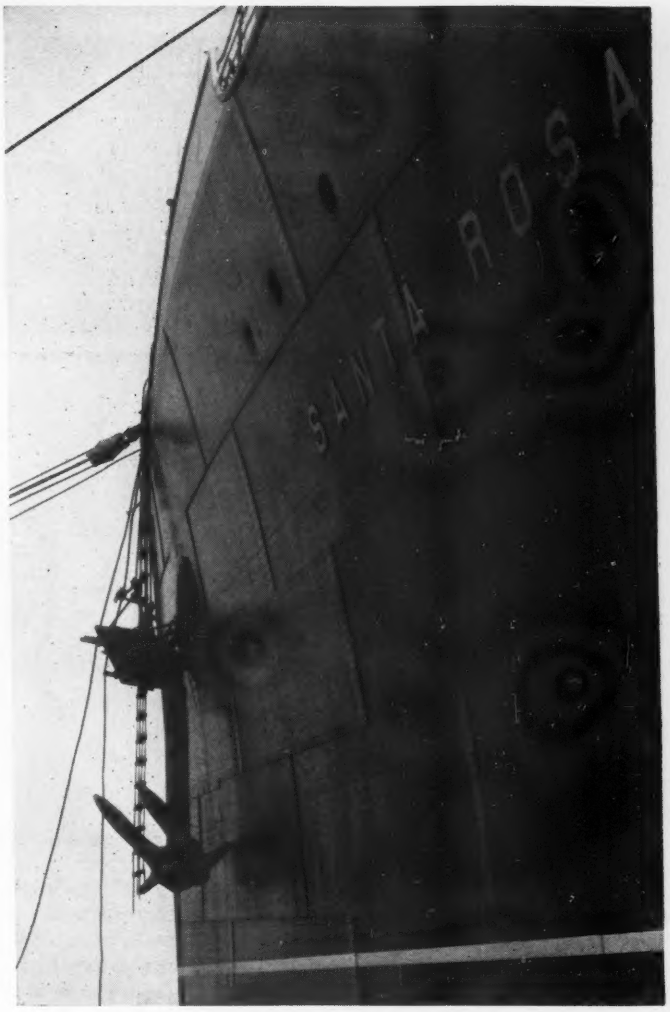
Courtesy, Grace Log.

THE "M. P. Grace," a full-rigged sailing ship of 1863 tons, built in 1875 and named for the brother and partner of W. R. Grace. She sailed around the Horn between New York and San Francisco in about 100 days. The four new Grace liners will make the trip through the Panama Canal, with calls at seven countries en route, in seventeen days.

# The First Vibrationless Steamships

*A New Era in Passenger Comfort Is Inaugurated by Four Fine Vessels of The Grace Line Designed by Gibbs & Cox, Incorporated, and Built by the Federal Shipbuilding & Dry Dock Company*






Courtesy, Grace Log.
**Sighting along the bow of the "Santa Rosa".**

A RENAISSANCE in American merchant shipping is, by all indications, at hand. After sitting on the side lines for many years, the United States is developing a merchant marine which has already reëntered maritime competition with the other great powers in a serious way. During the 10-year operative term of the Merchant Marine Act of 1928, a million tons of ships will slide down the ways of American shipyards and carry the Stars and Stripes to the far flung ports of the Seven Seas.

Some of these vessels have already gone into service, and their excellence of construction and fine records of performance are fitting proof of the ability of Uncle Sam to fabricate ships which compare favorably with those of any other nation. Noteworthy among them is the *Santa Rosa*, the first to be commissioned among four sister ships being built for The Grace Line's Panama Mail Service. The *Santa Rosa* sailed from New York on November 26 on her maiden voyage through the Panama Canal to California with calls at seven Latin American countries en route. It can truly be said that the *Santa Rosa* typifies a new standard of American shipbuilding. Not only have the owners, architects, and builders provided every facility for the comfort and enjoyment of those who will take passage upon her, but they have, moreover, given her a power plant that excels in efficiency and economy any of its size afloat. Since the *Santa Paula*, *Santa Lucia*, and *Santa Elena* are to be similar to the *Santa Rosa* in every respect, the same things will hold true of them when they enter service during the forthcoming few months. Each of the liners has an overall length of 508 feet, a maximum beam of 72 feet, and a displacement of about 17,000 tons. Accommodations are provided for 222 first-class passengers.

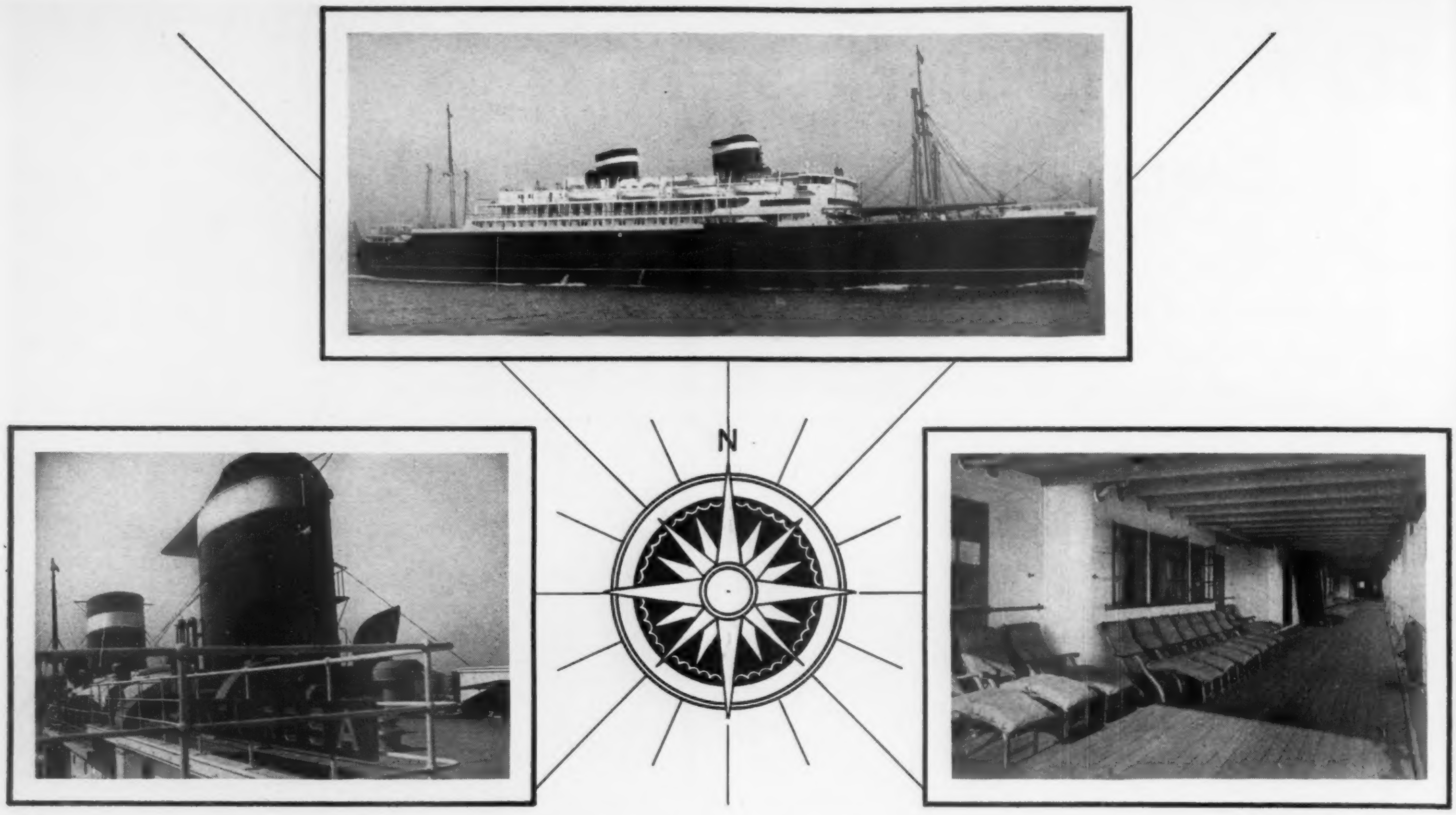
This new Grace fleet is the latest development in a maritime epic which began when William R. Grace, 80 years ago, founded in Peru the house which bears his name. It was rapidly extended throughout the west coast of South and Central America, then to New York and San Francisco, and to Europe. Latin America has, however, always been its stronghold.

In the beginning, Grace marine operations were conducted by sailing ships which rounded the Horn to Chile and Peru. Later, a steamship line was established to the same destinations via the Straits of Magellan; and The Grace Line was the first American service to ply from New York through the Panama Canal to the west coast of South America.

In the meantime, other maritime nations had put forth the idea that we were not a sea-minded people, and so industriously did they expound this theory that even Americans accepted it. Prior to the World War we had a fair amount of American-owned tonnage, but it was mostly foreign built and operated under foreign flags and manned by foreign seamen. There were American lines to the nearby Caribbean. The old Pacific Mail and the Oceanic Line kept the Stars and Stripes on the Pacific. There was one American line in the transatlantic trade which was kept there by a limited mail subsidy. In the other trades, where foreign competition was intense, it was impossible for American shipping companies to operate the higher-cost American-built vessels with the higher operating charges imposed by American laws. Certain industrial corporations maintained a few American cargo ships under American registry.

In 1914 we felt acutely our dependence upon foreign shipping. The vessels of the belligerents were, of course, subject to the attacks of submarines and commerce raiders. Congress was obliged, in August, 1914, to authorize the transfer of all foreign-flag vessels owned by American citizens to American registry, which had been previously restricted to American-built ships. This provided a nucleus of American-flag tonnage; and a considerable number of American ships was built by private companies between the outbreak of hostilities in 1914 and our entry into the war in 1917. The high freight rates which then prevailed made this possible.

When we entered the war, the necessity of transporting and supplying the American Expeditionary Force obliged the Government to engage in a gigantic and costly program of ship construction. The war-built fleet cost $3,000,000,000. It made a bridge to France. It turned the scales in the World War. It assured ample reserves of man power and munitions. But at the end of the war, when the test of commercial utility was applied, this Government fleet was found to be




Courtesy, Grace Line

**The "Santa Rosa" returning from her sea trials, and two views aboard her.**

sadly out of balance. It consisted, in large part, of cargo vessels of from 10 to 11½ knots speed, with a few higher-speed combination passenger-and-cargo ships originally designed for transport service. The Government did its best with these ships—supplementing a fair amount of privately owned shipping, which was then released from wartime service, to establish the foundation for an American Merchant Marine. Shipping Board lines were created to all the great markets not served by private-owned lines. In some cases, the Government allowed itself to enter into competition with private-owned lines. After the post-war boom subsided, these Government lines incurred enormous losses. The Shipping Board's annual deficits were far greater than the comparatively small amount which is now being expended in direct Government aid to privately owned lines. This brought forth a demand that the Government should retire from this business; and, gradually, several of the lines in the most important trades were purchased by private American shipping companies. But it was found impossible to divert to private use any large part of the war-built Government fleet; and a large portion of it was tied up in harbors and rivers. American citizens viewed the melancholy spectacle of these vessels gradually deteriorating because they were not of the specialized type which modern commerce required and because American operating costs were so high.

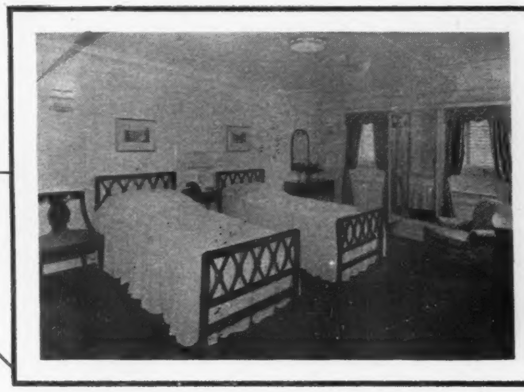
Other nations pursued a different policy. Following the war, they began to build ships designed for economical operation with which to gain their share of world trade. This situation extended until 1928, when the Congress of the United States concluded that something must be done about it. Keeping in mind the fact that it costs about twice as much to build a ship here as in foreign countries and that it costs more to maintain a vessel under American registry than under a foreign flag, the Jones-White bill previously referred to as the Merchant Marine Act of 1928 was enacted. This empowered the Government to grant mortgage loans at low interest rates to reputable companies for the construction of ships and to award contracts for the carrying of mails. The Jones-White bill strengthened the Merchant Marine Act of 1920, which directed the transfer of Government ships to private enterprise but which failed to provide aid sufficiently adequate to enable private operators to overcome our economic handicap in world competition.

In the acts of 1920 and 1928, Congress did an unusual thing in legislative practice. It declared a national shipping policy and stipulated that its object was the establishment of an American Merchant Marine adequate to carry the greater part of American commerce under the American flag and to provide vessels which would be useful as naval and military auxiliaries in time of national emergency. The act of 1928 reaffirmed the policy and sought to give adequate aid in place of the inadequate aid provided by earlier acts. But in return for this aid the shipowners assumed heavy contract obligations. They were required to maintain service on routes found by the Shipping Board to be essential to national commerce.

The promotion of commerce is quite as much a purpose of the act as the carriage of mails. The new vessels built with the aid of construction loans are required to be designed to specifications approved by the Navy Department. They are of the most modern and efficient type. These ships and all others subject to mail contracts are to be instantly subject to Government requisition in time of war. It is provided that, if vessels are so taken, the owners will receive only the fair actual value of their ships, without any enhancement because of the special circumstances which cause their requisition. Two-thirds of the members of the crews of all mail-contract ships must be American citizens. All officers of any American-registered ship must be citizens of the United States.

The administration of the Jones-White Act since 1928 has been liberal, and fortunately so. Were it not for this act, the American Merchant Marine today would be in retreat. Instead of meeting that fate, it has held its position in world trade; and to it is due, in no small part, the fact that while our foreign commerce has decreased it has decreased less than that of our competitors. The United States remains the largest exporter in the world. The Jones-White Act puts into effect a form of national resource which was visualized as necessary by President McKinley, who, in his last public address, said: "We must encourage our Merchant Marine. We must have more ships. They must be under the American flag, built and manned by Americans."

However, it is not sufficient that we have merely more ships. It is essential that they be on a par with or superior to foreign-built vessels with respect to passenger comfort, operating efficiency, and operating economy. Only in that way can they hold for America her share of world trade, for they must compete with the ships of other maritime nations. This thought was voiced at the launching of



Courtesy, Grace Line

**The appointments of the new ships provide every comfort for passengers.**

the *Santa Paula* by Commissioner S. S. Sandberg of the United States Shipping Board when he said: "The success of our Merchant Marine in meeting this competition will depend not so much on the number and tonnage of our vessels but upon the kind and quality of them. In the number and tonnage of ships the United States now ranks second among the maritime nations of the world. If efficiency and modernity be considered—as they must be—our position is much lower. We do not need more ships. We need better ships. We must have them! We shall have them!"

This, then, was the broad background of American shipping at the time The Grace Line, among other operators, elected to go into partnership with the Government, so to speak, and to invest close to $20,000,000 in the four Santa ships. Scarcely any boats had been built in this country since 1921; and Americans were reputedly not of a turn of mind to put together vessels that would stand close comparison with those built abroad, where notable developments had been taking place during our hiatus.

There were, however, several fortunate elements in the situation, and others were to manifest themselves. To begin with, The Grace Line was rich in experience on the seas, as is evidenced by the fact that ships flying its flag travel more than 1,000,000 nautical miles each year. Naturally enough, officials of the line had some definite ideas as to what they wanted and what they had to have to fill the requirements of the service into which the new ships were to go.

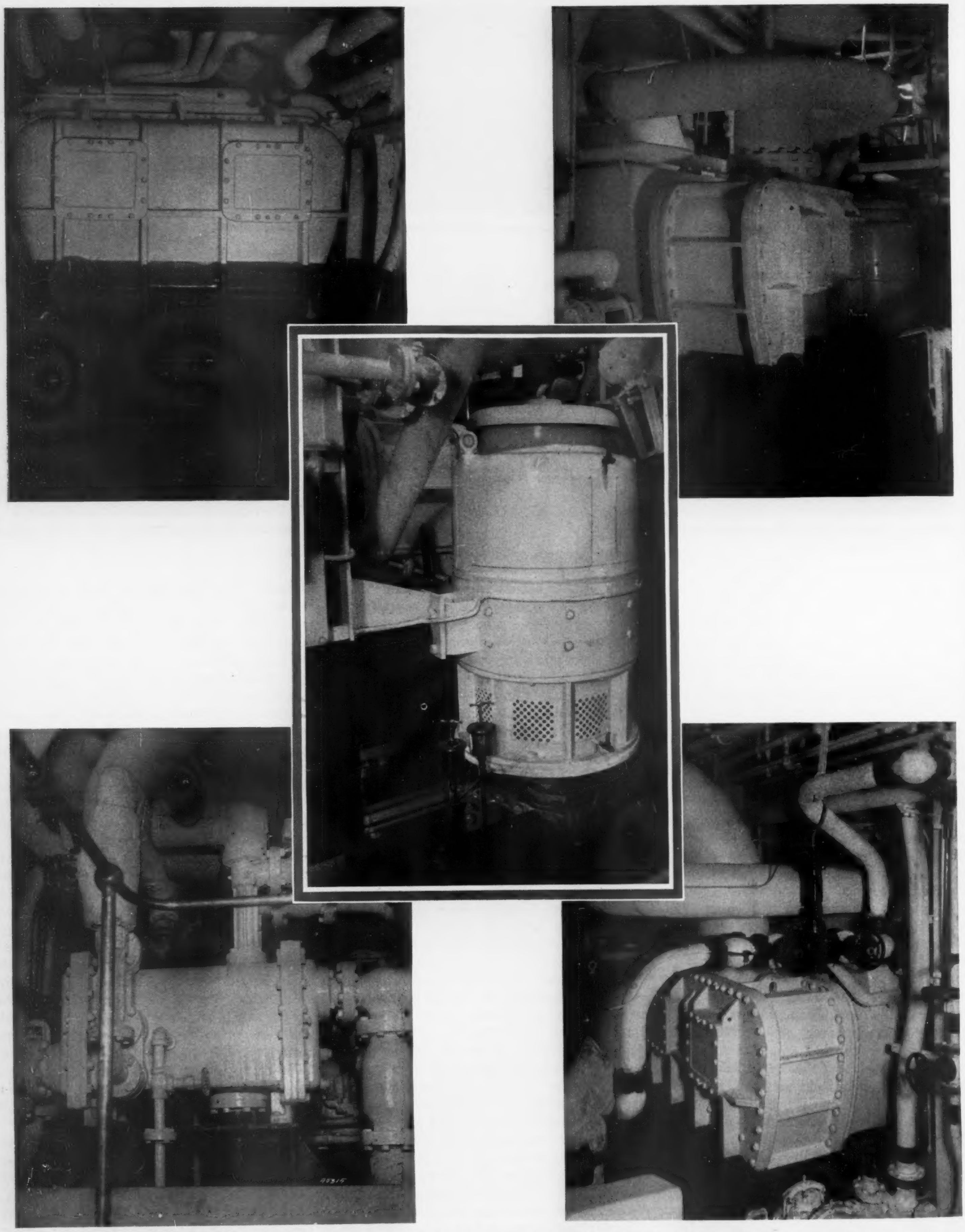
A second happy circumstance was the fact that certain American naval architects and shipbuilding concerns had been utilizing their periods of comparative inactivity by studying ways and means of improving the driving machinery of ships—that is, of providing greater propulsive power per dollar of fuel cost while meeting all the manifold demands and restrictions of power plants that go to sea. Two such firms were Gibbs & Cox, Incorporated, well-known marine designers, and the Federal Shipbuilding & Dry Dock Company of Kearny, N. J., which were subsequently commissioned, respectively, to design and to construct the four Santa boats. Accordingly, after the ideas of the owners of The Grace Line had been incorporated in preliminary plans and specifications prepared by Gibbs & Cox, the contractor was in a position to suggest modifications which would satisfy all requirements and, at the same time, serve to reduce the first cost, and hence the interest charges, and to lower the operating costs. Final details were then worked out jointly by the shipyard and the architects, and approved by the owners.

Broadly speaking, the important thing that was done in the case of these ships was the adaptation of some of the best practices of land power plants to marine service. It so happened that great advances in the economical utilization of fuel were made in electric generating stations of the United States during the years that shipbuilding was virtually at a standstill. These the Federal Shipbuilding & Dry Dock Company, and particularly its chief engineer, W. W. Smith, kept under close observation—in fact, put largely into effect in two oil tankers, the *G. Harrison Smith* and the *W. S. Farish* constructed for the Standard Oil Company of New Jersey. The outstanding efficiency of these vessels proved the correctness of their power-plant design, and the suggestions made for the four Grace liners were founded upon and backed up by the actual performances of the two tankers. An oil carrier, however, is vastly different from a ship which is intended for fast freight-and-passenger service and in which the comfort and safety of those aboard are of paramount consideration.

The measure of economy of a steamship is the amount of fuel required for all purposes per horsepower of effort realized at the propeller shafts. Naval engineers express it in pounds per shaft horsepower. Common denominators are used as between coal, diesel oil, and fuel oil; and in the case of fuel oil the basis is 19,000 B.T.U's per pound.

At the time the building of these four boats was under consideration, the newest Grace Line ship was the *Santa Clara*, which has turbine-electric drive. Oil is used as boiler fuel, and the plant operates with a fuel consumption of about .72 pound of oil per shaft horsepower. In selecting the machinery for these new Santa ships, several alternative arrangements were considered, and plans and specifications which were sent out for bids included three types: first, turbine-electric drive; second, single-reduction geared turbines; third, double-reduction geared turbines. In all three cases, the specifications called for the use of steam of high pressure and high superheat.

The third type of drive was finally selected and installed and was substantially in accordance with the original plans. The wisdom of this choice was demonstrated when the *Santa Rosa*, on her official trials off Rockland, Me., last October, recorded a fuel consumption of less than .6 pound per horsepower, based on total power used and oil of 19,000 B.T.U's per pound. This figure is



**Condenser equipment which contributes to the remarkable economy and reliability of the "Santa Rosa." Top, left and right—The inboard and outboard ends of one of the main condensers. Center—Vertical pumps for condenser circulating water are an innovation on American-built ships. The driving motor is shown here, the pump being beneath the floor plates. Bottom, left—Steam-jet vacuum pump which serves a main condenser. Right—The main condensers were fitted into restricted spaces with great adroitness.**

lower than that attained by some recently built American ships which are much larger and which, therefore, have greater opportunities for efficient utilization of power.

Designers of power plants on land and sea strive for the same primary objectives, which are: maximum reliability and maximum efficiency. The designer of a ship's power plant, however, has imposed upon him numerous inexorable requirements which do not apply to the land engineer. For one thing, to insure safety to passengers, cargo, and the vessel itself, it is vital that the full normal power, and even more, be available instantly in the event of an emergency. This necessitates that every essential element of the propulsion machinery be in duplicate. If the ship is to receive liberal patronage, it must provide carefully for passenger comfort, and to this end it must be as free as possible from smoke, noise, and vibration. The earning power of the boat will vary directly in proportion to the space available for passengers and cargo, and the power plant must, accordingly, be compressed into the smallest possible space. A multitude of incidental services related to the safety, comfort, and convenience of the passengers must be provided. These are so numerous that we shall mention here only the more important ones: a carefully isolated and guarded drinking-water storage supply; a distribution system which will furnish ice water under pressure to various outlets throughout the ship; a system to provide hot and cold water for washing and cleaning purposes wherever required; an adequate high-pressure water system for fire-fighting purposes; a system to provide electric light, heat, and power throughout the ship; a system to supply hydraulic power to operate numerous safety doors, valves, etc., from remote points in case of collision or other emergency; and a pneumatic system to furnish compressed air for tools, for cleaning, etc., wherever it may be needed.

That all these exacting requirements can be satisfied at all is in itself a tribute to the ingenuity of marine engineers. To meet them and, in addition, to provide for great fuel economy, would seem almost impossible at first glance. When one considers that all these things have been accomplished in the *Santa Rosa*—even to the point of achieving a fuel economy that would do credit to a land power station of twice her size—it is realized that the building of this ship constitutes a triumph in modern marine engineering.

That which has been and is being done in the case of the *Santa Rosa* and her sister ships, is the result of no one mechanical coup. It has come about through the combining of the manifold elements of the power plant, each carefully selected for its task and each fitted into the general scheme of compactness, reliability, and efficiency. It is truly a case of engineering tailoring.

The main propulsion plant consists of two General Electric cross-compound extraction-type turbines, each of which drives a propeller shaft through double-reduction gears. They are of the variable-speed and reversible type. Each turbine has a high-pressure unit, which operates at designed full load at 4,508 revolutions per minute, and a low-pressure unit which is rated at 3,528 revolutions per minute. Each turbine delivers 6,600 hp. to the shaft at full load: combined, they provide 13,200 hp. Normal operating conditions will call for 12,000 hp. These turbines are designed to use steam at 375 pounds pressure and 725° F., and to operate at 28¼ inches of vacuum.


Frequent stops in enchanting lands lend interest to the invigorating voyage aboard the new ships.

Steam conditions such as these have been successfully used in land power plants for ten years and longer, and are now being greatly exceeded. They are higher, however, than have ever before been specified for any ships built in the United States, with the exception of the two oil tankers previously mentioned.

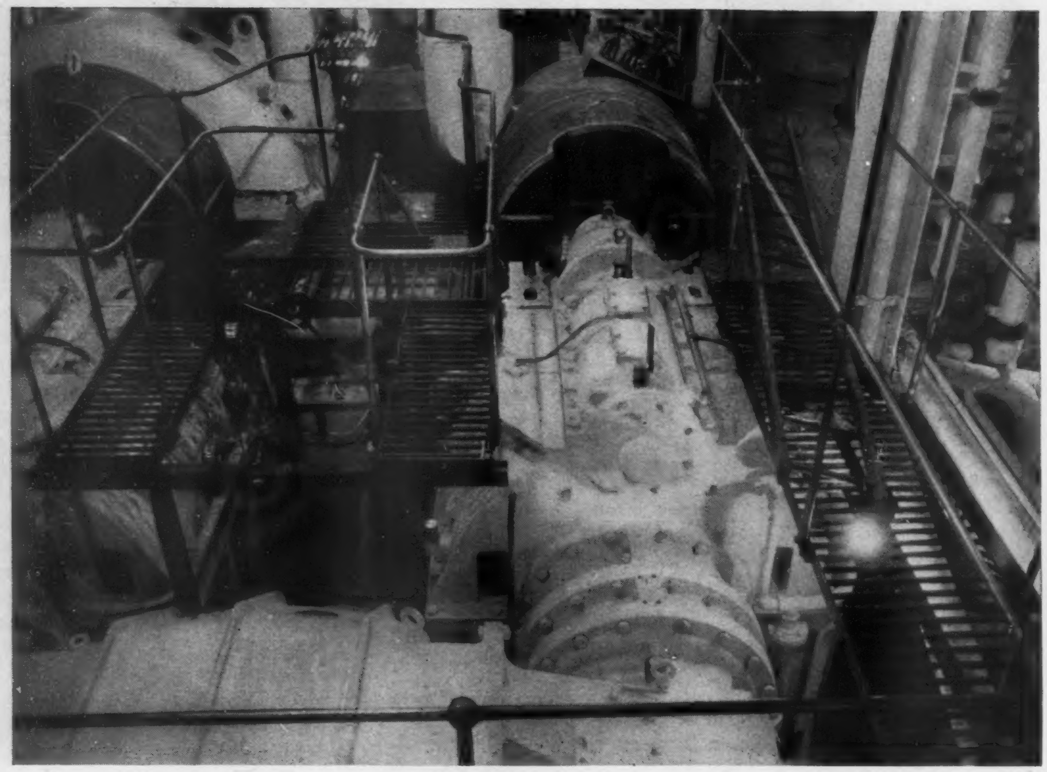
So far as is known, the efficiency of the turbines is higher than that of turbines in other ships of like power. They are unusually rugged because of their small size, and very safe because of their consequent low distortion from heat. On the trial run, including the trip to and from the course and covering some 1,000 miles, no vibration was felt despite the fact that the *Santa Rosa* was operated at various speeds and through a power range from 6,000 to around 14,000 hp. No noise was audible outside the engine room, and those on board had the feeling that the ship was gliding or coasting by its own momentum rather than that it was being driven forward by some mechanical means within its hull. It was impossible to tell from above decks whether the turbines were running at full load or at half load. This absence of vibration is due to the inherent characteristics of the rotative machinery installed and also to the rigid support in the form of unusually heavy steel foundations provided for the turbines and reduction gears.

The boilers are 3-drum, A-type units with economizers. Babcock & Wilcox Company and Foster Wheeler Corporation were each awarded contracts to furnish boilers for two of the four ships. On test, one of the Foster Wheeler boilers, which will be installed in the *Santa Paula*, showed an efficiency of 87.6 per cent, based on the high heat value of the oil burned. This figure is a high record for a ship's boiler built in the United States or elsewhere. The boilers are compact and possess several notable features which make for satisfactory performance. The furnaces are unusually large and make possible thorough mixing of the fuel oil and air, which results in complete combustion within the furnaces, thus rendering the stacks free from smoke and soot and keeping the ample decks, where the passengers will spend much of their time, remarkably clean and habitable.

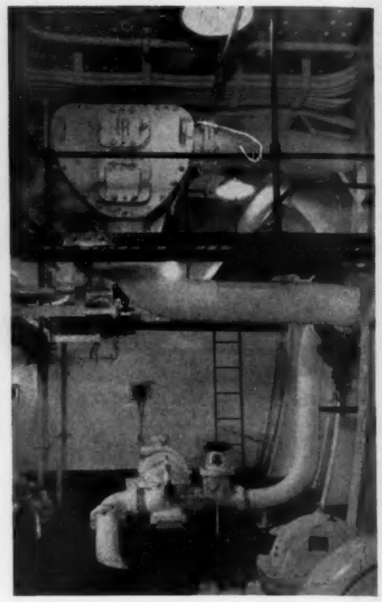
Every precaution is taken to safeguard the purity of the boiler feed water to minimize fouling of the boilers. A steam system of this sort demands water so free from impurities that it is no exaggeration to say that much of the water we drink would be unsuitable for the purpose. The water supply is distilled before entering the system, and thereafter circulates through closed vessels and piping and is used over and over again. Provision is made for routing this water through evaporators for redistillation at any time. The system is so designed and so operated that normal make-up water, which must be added, amounts only to .5 to 1 per cent of the total per day, as contrasted with the 2 or 3 per cent required on old-style ships. The feed water is deaërated in order that no oxygen will be carried into the boilers and induce corrosion.

Air for combustion passes first through jackets surrounding the walls of the furnace and acquires heat which raises its temperature to 150° when the boiler-room temperature is 90° to 100° F. As a result, tests on one of the boilers showed an unaccountable heat loss of only 1.5 per cent, compared with 4 to 5 per cent for the average marine boiler. Here, then, is a fuel saving of about 3 per cent, obtained without cost.

The large volume of the furnaces, together with the adequate jacketing, makes it seem highly probable that no rebricking or other major repairs will be required for a long time—



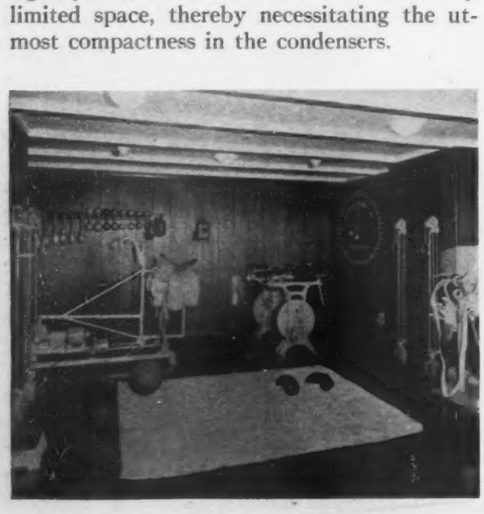
**Looking over the reduction-gear casing at one of the two duplicate propulsion turbines. Each turbine has a high-pressure and a low-pressure side.**



**Overhead is the end of a condenser for an auxiliary turbine. Below it is the Cameron pump which supplies it with circulating water.**

probably not for ten years, whereas on most types of boilers rebricking is necessary within two or three years.

Correct and efficient functioning of the surface condensers is essential to the economy and reliability of the boilers and turbines in modern marine power plants. The highest vacuum consistent with economical power expenditure by the circulating pumps and other auxiliaries is required fully to realize the inherent economy of the turbines. Even more important, reliability demands that there be positive protection against salt getting into the boiler feed water by admixture of sea water used for condensing purposes. In the case of the *Santa Rosa*, the foundations for the main turbines and gear casings had been made so massive to secure rigidity as to further restrict the already limited space, thereby necessitating the utmost compactness in the condensers.



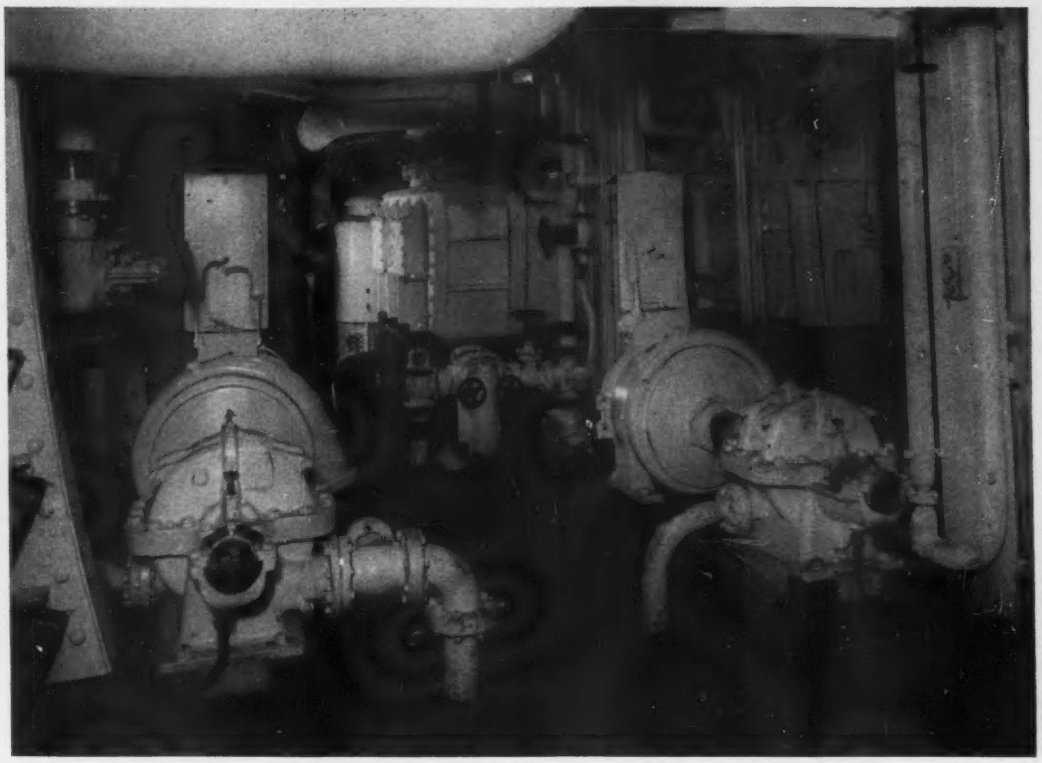
**A corner of the "Santa Rosa's" completely equipped gymnasium.**

Because of the exacting conditions, it was believed physically impossible to install condensers of higher vacuum-producing power than 28¼ inches, based on sea water of 75° F., which is the average temperature that will be met on the route to be traveled. The problem thus presented was turned over to Ingersoll-Rand Company, whose patented condenser design had previously proved capable of meeting severe operating and space requirements. That company's condenser specialists were able to show, by actual records of marine condensers already in service, that they could meet the rigorous conditions and still provide a vacuum ¼ inch higher than that specified. An additional quarter inch sounds rather insignificant, but actually, because of the properties of expanding steam in the vacuum range, it adds 2 per cent to the power of the turbines. It means that the *Santa Rosa* can command 280 additional horsepower when extra power is needed, or save 2 per cent in fuel cost at other times.

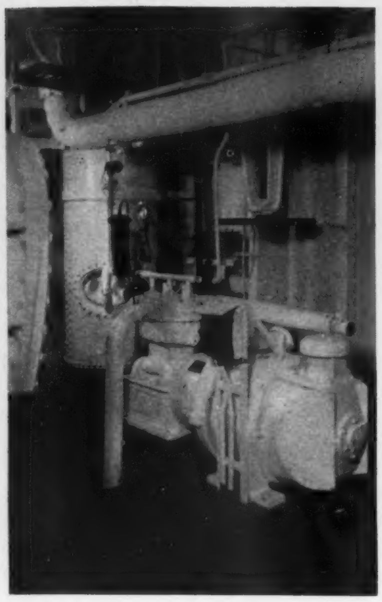
As some of the photographs show, the main condensers are fitted into the spaces beneath the turbines and between the foundations. Each condenser is solidly bolted to the low-pressure turbine exhaust nozzle and is free to move with it as it expands or contracts. The weight of the condenser and its operating water is suspended partly from this nozzle and is partly supported on coiled springs enclosed in housings which are fitted with crossheads that allow the condenser to move laterally with movements in the turbine casing. This spring support system was designed and built by the Federal Shipbuilding & Dry Dock Company.

Each main condenser is served by a Cameron Type 18 VFV centrifugal pump rated at about 7,000 gallons per minute and 13 pounds total head and driven by a 75-hp. motor. In order to conserve space, these pumps are arranged vertically, and are the first to be so installed on an American-built ship. The drivers are above the floor grating while the pumps are directly below them, but readily accessible. The condensers are mounted transversely beneath the outboard, low-pressure turbines; and inlet and outlet water connections are so situated that only a few feet of piping is required for them. All three auxiliary turbines are served by I-R condensers of the same design as the main condensers. These condensers will be called upon to operate with cooling water of widely varying temperatures during the course of each voyage, and they are designed to give high vacuum in northern waters or in the tropics. On the trial run of the *Santa Rosa* they performed excellently and demonstrated their high vacuum-producing capabilities.

The net result of the skillful designing and sound engineering which Gibbs & Cox, Inc., and the Federal Shipbuilding & Dry Dock Company have manifested in this ultra-modern marine power plant is to give the *Santa Rosa* an overall thermal efficiency of about 24 per cent. This mark, which was attained during the official trials, is much



In the foreground are duplicate Cameron fire and sanitary pumps. Eleven other Cameron pumps perform a variety of services on each ship.



Compressed air aboard ship is supplied by this Type 20 compressor. Overhead is the end of a condenser for a small auxiliary turbine.

higher than has been reached previously by a steamship, regardless of whether it was built in the United States or abroad. The fact is that such an efficiency compares well with the performance of modern land power plants of considerably greater size, whose operating conditions are far more favorable.

A great deal of electric power is required on a ship to drive auxiliaries and to furnish light. The *Santa Rosa* has an electric generating capacity sufficient to meet the normal requirements of a city of 6,000 persons. An unusual feature which effects a saving conservatively estimated at 3 per cent in the cost of generating power is the driving of the main generators from the main propulsion gears. Each of the two 500-kw. units is connected to and driven by a shaft extension from the low-speed, low-pressure pinion, the generator being mounted just aft of the main gear casing. The reason for this arrangement, which was first employed on the oil tankers previously mentioned, is that the efficiency of the main turbines is 78 per cent, as against 50 to 62 per cent for the auxiliary turbines. Two General Electric steam-driven turbine generators are also provided as auxiliaries; and when the main turbines slow down to 70 per cent of full speed, the generators attached to them are automatically disconnected and the auxiliary generators, which have been idling along, pick up the load and continue electrical service without interruption or appreciable visible disturbance. A General Electric 200-kw., steam-driven turbine generator is installed for use when the ship is at dock or at other times when only small amounts of power are required. Automatic voltage regulation is provided for the attached generators throughout the full range of speed from maximum to about 70 per cent of the normal ahead speed of the main units.

The propellers, which are 3-bladed and about 17 feet in diameter, were originally intended to turn at 120 revolutions per minute, which is usual practice. To obtain higher propulsive efficiency with lower power input, their speed was reduced to 95 revolutions. Model tests indicated that a saving of as much as 10 per cent might be made as a result. This promise was borne out during the official trials of the *Santa Rosa*.

A feature which is being used for the first time on an American-built ship is the hydraulic operation of the bilge valves. There are 40 or 50 of these valves, which have to be controlled from the deck in case of an emergency when the engine room cannot be entered. The usual method of doing this is through mechanical gearing which utilizes bevel gears and knuckle joints. On the *Santa Rosa*, however, there was installed the Atwood & Morill system in which oil at 400 pounds pressure actuates the valves.

A factor in the general efficiency of the *Santa Rosa* is the skillful design of the hull form, which was developed by model tests. The hull has what is known as a cruiser stern and a moderately bulbous bow, with somewhat hollow lines forward.

The *Santa Rosa* was built under a speed guaranty of 18.5 knots. Actually, on her standardization trials, she made 20.05 knots, which means that she can easily meet a 17-day schedule on a route which now requires 22 days by older Grace Line ships.

The new ships are being built in strict accordance with the rules of the International Convention of Safety of Life at Sea, a fact which insures their soundness and reliability under any and all conditions they may meet.

In a previous article we described the general arrangements of the ships and the almost lavish provisions that have been made for the comfort and enjoyment of the passengers. Space limitations will not permit further details regarding these features, but some of the accompanying illustrations will convey to the reader an idea of the pleasure that awaits him should he be fortunate enough to have his name upon the sailing list.

The largest outdoor swimming pool on any American vessel.

# Mining Rock Salt in British Isles

*An Old-Established Industry in the Cheshire District of England*

A. M. HOFFMANN

**Drilling horizontal shot holes after undercutting.**

**Blocks of salt produced in the Cheshire District by the evaporation of brine from saline springs.**

Photo Acme.

**Laden cars ready for hoisting.**

REOPENING an abandoned salt mine within the brief span of a fortnight might well be termed an achievement, and credit for it is due the Salt Union of Cheshire, England. The property in question is the Meadow Bank Mine, at Winsford, which was closed down in 1888 after 33 years of activity. Cheshire, it should be said, has for centuries been the center of a thriving salt-producing industry—in fact, since about 1670, when the main deposit at Northwich was discovered by an engineer prospecting for coal. But even for decades before that the natural brine springs of the region were the source of an abundant supply.

As many as 107 mines have been worked at Northwich. These are now flooded for the most part—the reason for the reopening of the Meadow Bank Mine, the only one of three at Winsford that was not submerged. This mine was actually in production two weeks after the work of rehabilitation was begun; and within seven months it was in complete running order and equipped with every modern facility that has made of rock-salt mining, as some one has expressed it, a clean, healthy, and safe occupation.

The bulk of the rock salt mined at Winsford varies in color from light yellow to dark red owing to the presence of marl with which it is associated. Occasionally, however, pockets of clear white salt of great purity are found. The formation consists of two beds separated by a 30-foot layer of marl. The uppermost bed is 70 feet in thickness and 253 feet below the surface, while the lower stratum lies at a maximum depth of 474 feet and is 121 feet thick. The area now being operated covers about 12¾ acres.

The underground workings are reached by two shafts each 4 feet square and 457 feet deep. These are timbered to a point 200 feet down from the top, or well below the depth to which surface water penetrates. The mine, today, is a labyrinth of lofty chambers or rooms divided off by pillars of salt which are left standing to support the roof. These pillars, of which there are now 52, are from 20 to 30 feet high, 108 feet square, and spaced on 75-foot centers.

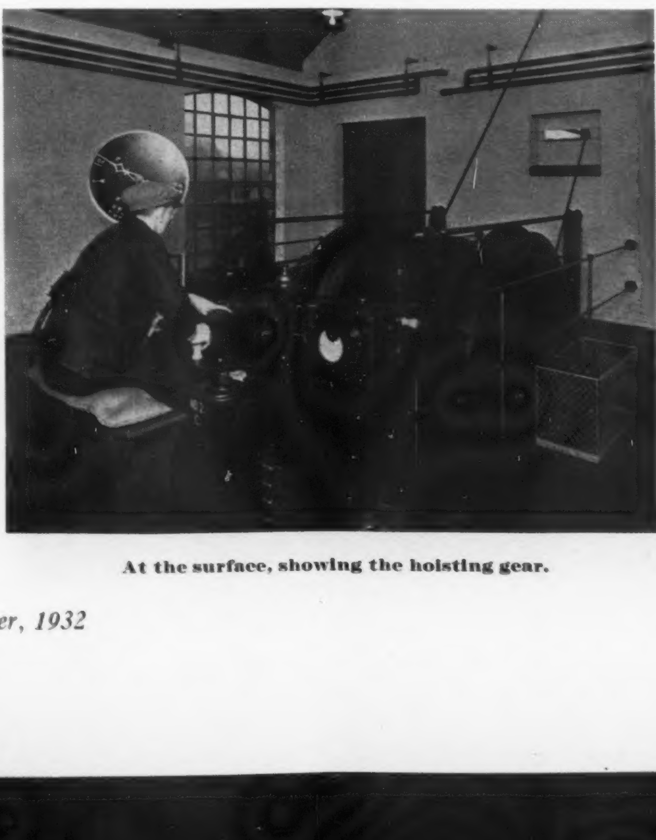
Undercutting the hard rock-salt face immediately below the roof in advance of drilling and blasting.

The practice at Winsford is to drive wide galleries and to keep what is termed the "roofing", the part immediately below the roof and from 6 to 7 feet deep, a number of feet in advance of the rest of the heading. The lower part or bench is then removed in a series of steps. The roofing is undercut at both the top and the bottom to a depth of 4 feet—the electrically driven cutters which have been provided for this work penetrating the hard rock at the rate of from 4½ to 9 inches per minute. After undercutting, horizontal shot holes are drilled at an angle to the face with "Jackhamers". These holes are loaded with varying amounts of explosives, depending upon their location. For those above the bench, from ½ to 1 pound are used, while those in the bench are charged with a maximum of 2 pounds which is sufficient to bring down as much as 20 tons of salt at a time. The charges are set off with the slow match-type of fuse. In this connection it is interesting to recall that fuses made of wheat straws once served for this purpose in the Meadow Bank Mine. The straws, up to 24 inches long, were filled with fine gunpowder and sealed at one end with a wick and at the other with tallow. After firing, the roof is trimmed with pneumatic picks; and pieces of rock salt that are too large for handling are split up with air-driven paving breakers.

The excavated material is loaded into cars and transported to the bottoms of the shafts for hoisting to the surface—the hauling being done by 20-inch-gauge storage-battery locomotives. Close to the foot of each shaft there is a small station for recharging the storage batteries. The winding gear is driven by a 45-hp. motor and has a 6-foot-diameter drum. To prevent confusion of signals, the hoist is equipped with an indicator that repeats the last order given. The mine is well-lighted throughout by electricity—floodlights being used at the working faces to assure adequate illumination. The temperature underground remains fairly constant the year round, at 54° F., the variation at no time exceeding a maximum of 1°. The atmosphere below ground is good, as there are no noxious gases present to vitiate it or to cause explosions, thus making for ideal working conditions regardless of the season of the year.

The rock salt that is not sold in lump form just as it comes from the mine is delivered to and run through a thoroughly up-to-date crushing plant that is located close to the headframe of one of the shafts. From there it is loaded directly in to ships or on to barges by means of a long rubber belt conveyor. Another source of salt are the natural brine springs of the region which are still being made to yield their saline content as they did in the centuries past and long before the beds of rock salt were discovered. This is now obtained through evaporation in both open and multiple-effect vacuum pans.

*Note: The photographs of the Meadow Bank Mine are reproduced by courtesy of The Industrial Chemist, London.*



At the surface, showing the hoisting gear.

## TINTED FINISHING MATERIAL FROM BY-PRODUCT LIME

LIME dust that has accumulated during a span of years in the production of hydraulic building lime is being turned into a marketable commodity by the Stettin Portland Cement Company, Germany, which, for want of a better use, has until of late added it to lime sold for masonry purposes. The extreme fineness of the by-product, and the great quantities that could not be disposed of in that way, led the company to experiment in the belief that it had commercial value. To make a long story short, it has, as a base for colored finishing limes. These are now being put out as a side line in six standard shades—gray, yellow, red, violet, brown, and green. The coloring matter, as far as it is practicable to make it, is light fast and lime fast.

Mixed with sand, the material is used as an exterior and interior finish for walls, ceilings, etc., and is said to possess the strength of cement. It is worked like ordinary mortar, and can be prepared so as to give a washable surface. The limes come in several grades, and can be applied by the spray method directly as a rough or smooth finish, or the surface to be coated can first be gone over with lime cement or mortar. Owing to its lightness, 100 kilograms, 220 pounds, of the colored lime will make 990 pounds of finishing material, or enough to cover an area of approximately 1,000 square feet with a thin coat or 190 square feet with a rough coat 0.4 inch thick.

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An interesting feature of the recent building fair held at Leipzig was a display of glass blocks which are being used in Germany for structural purposes. The large aerodrome at the Munich Airport is built of these blocks which, besides admitting light, possess a high degree of insulation against heat, cold, and noise.

# New Process of Decorating Stainless Steel

COOKING pots and pans, buttons, and beautifully decorated panels for architectural purposes apparently have little in common, and yet certain of them are closely related because the same metal has gone into the making of each. The metal is chromium steel or, as it was originally called, stainless or rustproof steel. It is not so long ago since stainless steel first put in an appearance; but since that time there has been produced a long list of chromium-steel alloys having many and diverse applications.

"Nirosta", for example, contains 18 per cent of chromium and 8 per cent of nickel. This material has supplanted the plated metal on some makes of automobiles, and large quantities of it is used as trim on the Chrysler and Empire State buildings. However, it is not the object to enter into a discussion of these various noncorrosive alloys, but, instead, to deal with a newly patented process for ornamenting high nickel-chrome steel, which is in increasing demand for decorating the facades, doorways, and lobbies of buildings.

The process was developed in the plant of the United Metal Products Company of Canton, Ohio, and differs radically from the method generally employed. Instead of reproducing the designs by etching—much as glass is frequently embellished, the metal is spray painted—the resulting work being in two sharply contrasting shades of silver gray that are very pleasing to the eye. The process is no longer in the experimental stage; and the company is now engaged in turning out panels of a highly artistic character that lend themselves well to the indoor and outdoor decorating of stores, railway stations, public and private buildings, etc.

Now let us see how the designs are transferred on to the metal. To some extent the procedure is not unlike that followed in cutting letters, scrolls, and other ornamental features in stone, glass, and wood, except that spray-painting takes the place of sand-blasting. Sheets of the nickel-chrome steel, with a Tompico or other smooth finish, are cut to size if but one panel of a kind is desired, or they are marked off in panels if the same decorative scheme is to be reproduced a number of times. This is done in order to facilitate subsequent operations. In the case of repetitive work, a strip of identical stencils is placed upon the sheet. The stencils are made of copper.

The exposed surfaces are now ready for spraying, usually with three coats of lacquer—two black, and an intermediate one of gray. After each application the panels are run into a furnace where they are allowed to remain for 30 minutes so that each coat may have a chance to bake thoroughly. With the lacquering completed, the sheet is acted upon by brushes which give the bare surfaces—the background for the *motif*—a dull finish. The polishing is continued until only the primary coat of black lacquer is left. It is to warn the operator when to stop rubbing that the second coat is gray in color—he knows when that is worn off that the sheet is in condition for the next stage of the process. That consists in removing all the remaining lacquer with a special paint solvent. After that the surface is given a final polishing with whiting, and the sheet is cut into its respective panels.

The accompanying photographic reproduction of one of these panels gives no idea of their beauty nor of the richness of the effect produced by the bright, satiny design upon the dull silvery background. Besides being highly decorative, they are also durable and noncorrosive, a combination of qualities that makes this new order of metalwork admirably suited for architectural purposes.

# Adding Years of Service to Great Britain's Longest Railroad Tunnel

S. J. PEARSON


"Cornish Riviera" express leaving Paddington Station, London.

Severn Tunnel and Connecting railway lines.

*Bore Beneath the Severn River is Strengthened by Injecting 8,700 Tons of Grout into Surrounding Strata*

EXTENSIVE work has recently been conducted in the Severn Tunnel of the Great Western Railway Company in Great Britain to strengthen the structure after nearly half a century of service and to protect it against the deteriorating and destroying influences of water. The operations involved the driving of 4,334 rock-drill holes, which aggregated 22,354 feet in length, and the injection through them of 8,702 tons of cement grout to reinforce the lining of the tunnel and two shafts.

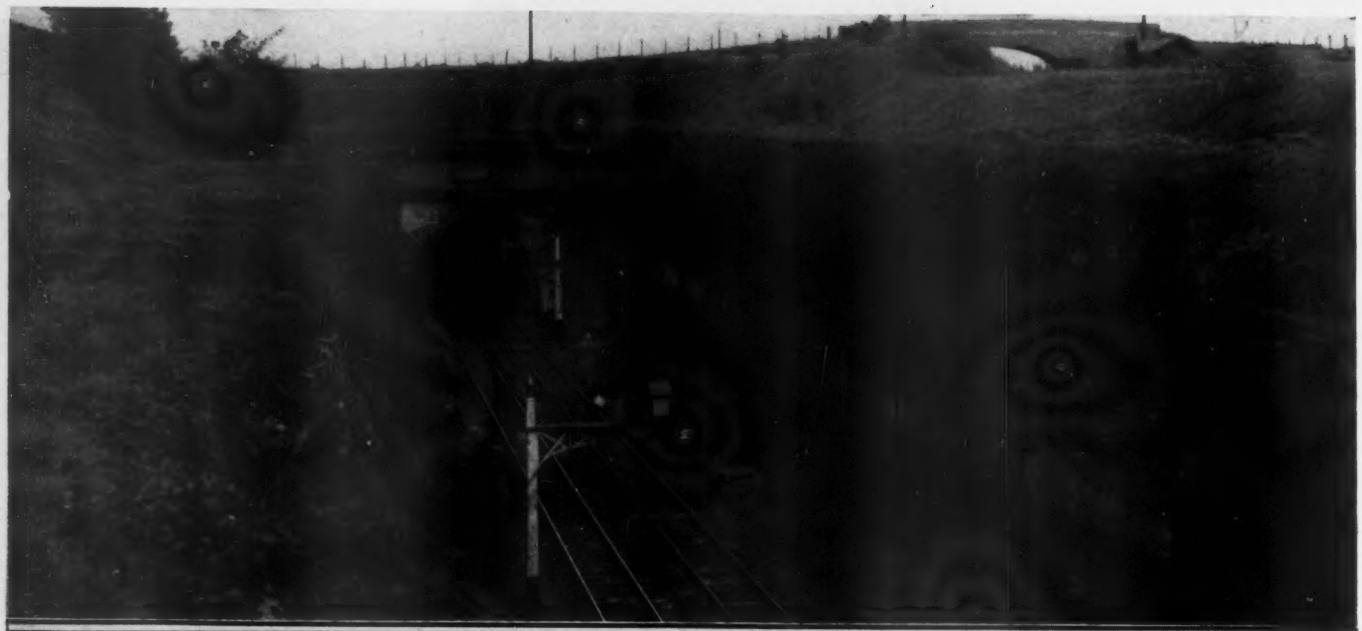
Aside from being an interesting example of engineering maintenance work, the undertaking is noteworthy because it has been carried on without interfering with the normal week-day schedules of a busy railroad. Under the terms of the contract, the workmen were allowed unrestricted possession of the tunnel only during a portion of each Sunday. Although it was stipulated that operations should be carried on 24 hours a day, the only concession made to the contractor on week days was to limit the maximum speed of trains through the bore to 30 miles per hour.

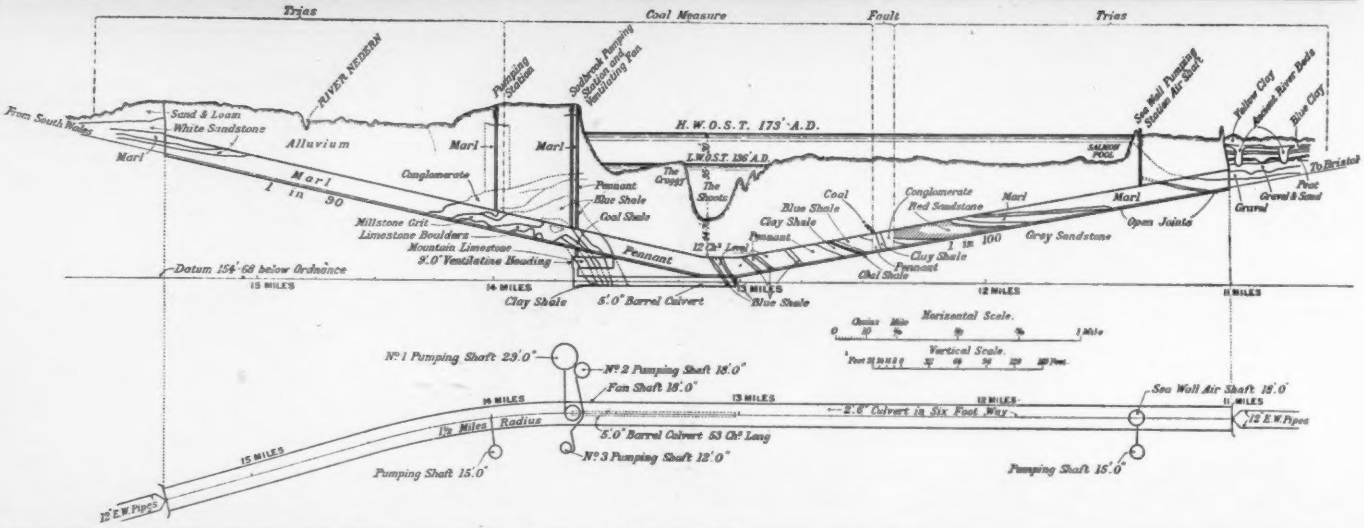
The Severn Tunnel is the longest railroad bore in the British Isles and one of the longest subaqueous tunnels in the world. It links Monmouthshire on the west and Gloustershire on the east, and has a total length of 4.35 miles, of which approximately 2.25 miles run beneath the tidal estuary of the Severn River. Its construction was begun in 1873 and concluded in 1886, the work having been impeded by flooding and other adverse conditions. The cost of construction was approximately $10,000,000.

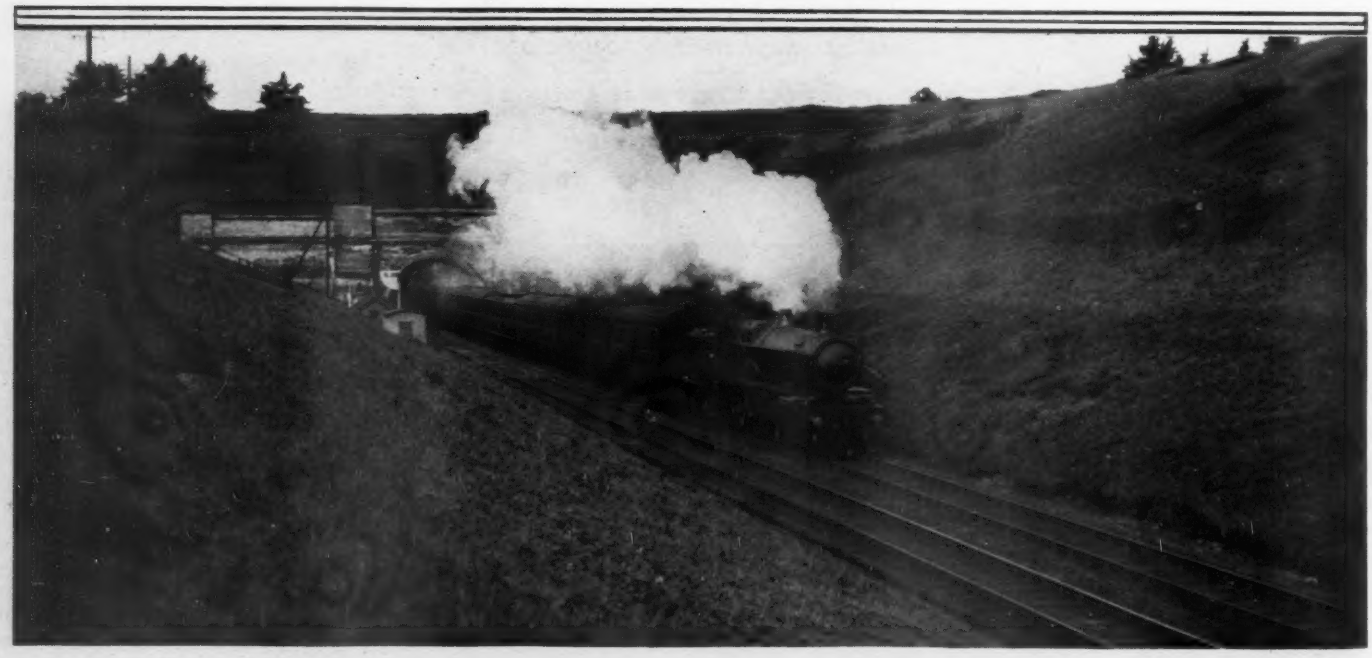
Although the shield-and-compressed-air method of tunneling had been successfully used prior to that time and cast iron had been demonstrated to be an effective material of lining, the Severn Tunnel was driven without the employment of either of these agencies. A 15-foot shaft was first sunk to a depth of 200 feet on the Monmouthshire or western bank of the stream, and from it bottom headings were driven to the east and, later, to the west. These operations, together with the sinking of three additional shafts, had gone on for six years when flooding of the headings forced their suspension. The railroad company, which had performed the work up to that point, then let a contract to T. A. Walker for its completion. The tunnel was timbered as excavation proceeded and was lined with 27-inch walls of brick. The bore is horseshoe shaped in section, has a maximum width of 27 feet, a maximum height of 25 feet, and accommodates two lines of tracks.

The tunnel is in the Trias and Coal Measure formations, except on the eastern end where it passes through gravel. Most of the ground penetrated is marl, but at certain zones the line cuts through other materials, principally shale, sandstone, limestone, and coal. During construction it was apparent that some of the overlying sediments were fractured; and at times the river water broke through the roof making it necessary to plug the gap with clay deposited from above.

When the early work revealed that much water was finding its way into the headings, the original design was altered to lower the tunnel by 15 feet beneath the Shoots or low-water channel. This resulted in steepening





**At the top and bottom, respectively, are pictured the Welsh and English portals of the tunnel. In the center are profile and plan drawings of the Severn Tunnel.**

the gradient from 1 foot in 100 to 1 foot in 90 on the western or Welsh side. As completed, the bottom of the tunnel is 60 feet below the river surface at low-water level and 100 feet at high-water level. The minimum cover is 30 feet, this being near the eastern side where there is a depression in the river bed designated as the Salmon Pool. This deepening of the tunnel line perhaps actually served to accentuate rather than to allay difficulties with water, for it was found that some of the greatest dangers and troubles resulted from inrushes of land water rather than of river water. One such underground flow that was tapped proved of such proportions that it was designated the Big Spring. The source of this ground water is not definitely known, but it is believed to have some connection with the River Neddern which, in dry seasons, disappears entirely at one point only to gush out of the ground a little farther on and resume its way. The explanation is that the river encounters broken and fractured strata where it loses its water.

Regardless of their origin, the subterranean flows in the area through which the tunnel passes have proved a source of annoyance since the work was first undertaken and have served to augment the difficulties occasioned by the river water. In 1924 excessive leakage from overhead was experienced, the water coming into the bore through an open joint or "pipe" which developed at a point about a mile from the eastern portal. As the mouth of this opening was accessible during low-water periods, it was possible to seal off the flow with concrete and other materials poured in from above. Similar troubles occurred in 1929 and were treated in like manner.

The builders of the tunnel left a very complete and accurate record of the character of the strata through which it passed. Study of these data and of their relation to the recurrent infiltrations tended to prove the existence of broken and faulty formations above the tunnel, particularly along a section of about three-quarters of a mile near the eastern end. It was felt that special measures should be taken not only to strengthen the brickwork lining of this portion of the tunnel but also to fill any voids that might exist between the outside of the lining and the surrounding ground so as to consolidate as far as practicable the material between the top of the tunnel and the bottom of the river bed. It was apparent from the outset that the only available method of doing these things was to force cement grout into and through the brickwork under a pressure sufficient to overcome the hydrostatic pressure which varied with the tidal flow of the river overhead.

The Francois Cementation Company, Bentley Works, Doncaster, was invited to submit a bid for doing the required work along a half-mile section of the bore embracing the length in which the 1924 and 1929 breaks had occurred. This was in the nature of a preliminary contract to determine the efficacy of the treatment that had been decided upon. Its proposal being acceptable, the Francois Cementation Company made preparations during October, 1929, for the work, and the first injection hole was drilled on November 3 following.

Buildings to house the equipment were constructed at the railroad company's Sea Wall Pumping Station on the eastern bank of the river. A cementation plant was installed there consisting of four Francois steam-operated cementation pumps complete with electric-driven mixing units and water-supply pumps. To furnish compressed air for operating the rock drills, there were provided two Ingersoll-Rand Class ER-1, 35-hp., stationary

**Chepstow Castle, Wales, near the Severn Tunnel.**

compressors, driven by Carels Type PO oil engines, and one I-R Type 20 portable compressor with a capacity of approximately 200 cubic feet per minute. The plant also contained a No. 50 drill-steel sharpener and a No. 25 oil furnace.

The necessary pipes for conveying the grout into the tunnel and for supplying water and compressed air to the rock drills were led down the adjacent ventilating shaft and thence along the course where the work was to be carried on. Connections were fitted at intervals for hose take-offs to the injection holes and to the drills.

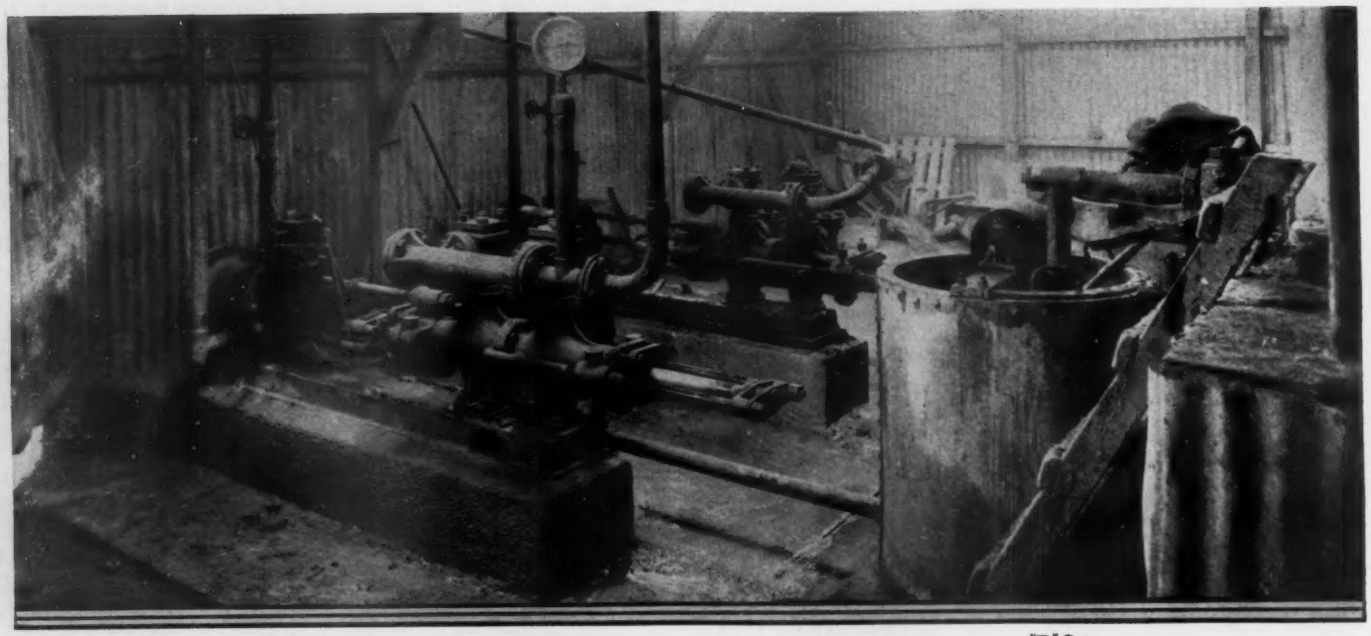
One of the accompanying diagrams shows the arrangement of the drill holes with respect to the cross section of the tunnel lining. The "A" and "K" holes, in the invert or bottom of the tunnel, were drilled to a total depth of 10 feet and reached points 4½ feet below the lowest point of the invert. "B" and "H" holes were drilled 4½ feet; "G" and "C" holes from 4½ to 5 feet; and "D", "E", and "F" holes 3 feet, or just through the lining. The spacing of the holes along the line of the tunnel varied according to conditions. It had been provisionally decided to drill the "A" and "K" holes in the invert every 66 feet on each side and to stagger them, making the interval between successive holes 33 feet. Throughout the first 1,000 feet, however, water under pressure was frequently tapped and the interval was reduced to 11 feet. The spacing of the other holes also was subject to change according to the quantity of water encountered.

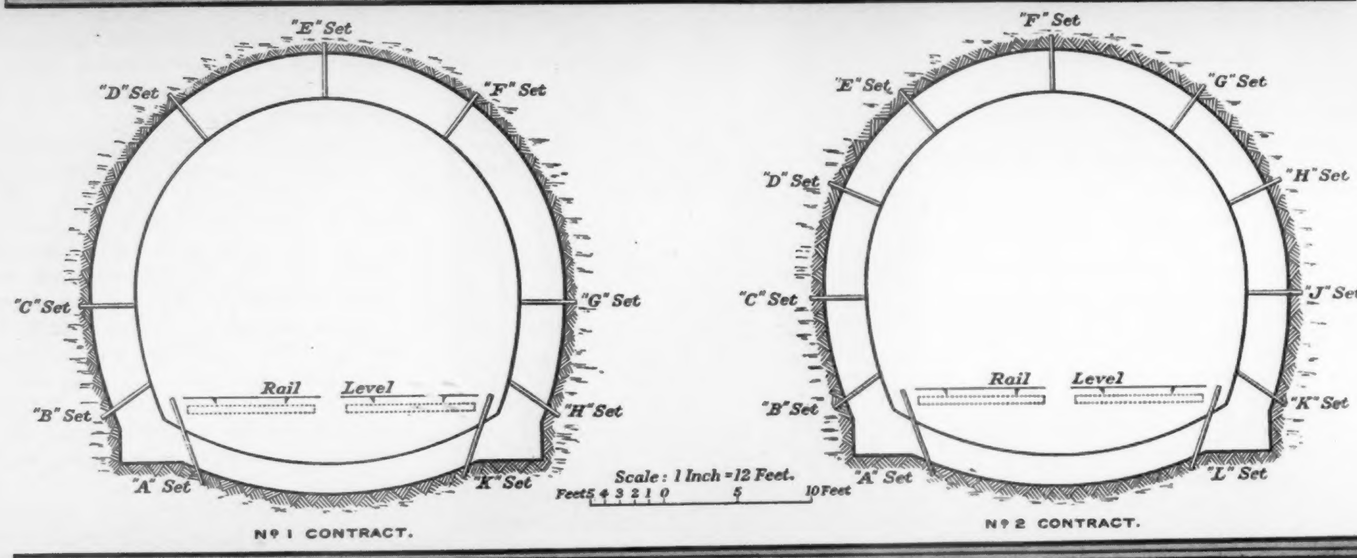
The drilling of these holes through the side walls was done from drill carriages built to run on up-and-down tracks. Each carriage was equipped with an I-R Type S-80 drifter drill. Holes through the crown were drilled from a carriage which ran on the two inner rails of the up-and-down tracks and on which were mounted three Type L-74 drills. These carriages could be used only on Sundays. During week days they were stored on a siding outside of the tunnel. In order to move them, the stages were loaded on to railroad trucks by means of a hand winch fixed on top of the Sea Wall Station ventilating shaft, the operations being carried on at the bottom of the shaft.

The holes through the brickwork had a minimum diameter of 3⅛ inches, while those in the surrounding strata were 1⅞ inches. The larger holes in the lining permitted the calking of the injection pipes throughout their course through the brickwork in order to prevent the development of pressure on the inner rings of the lining. This calking was thoroughly done with spun yarn as soon as the pipes were inserted in the holes. Whenever any considerable volume of water was encountered the pipes were capped pending grouting.

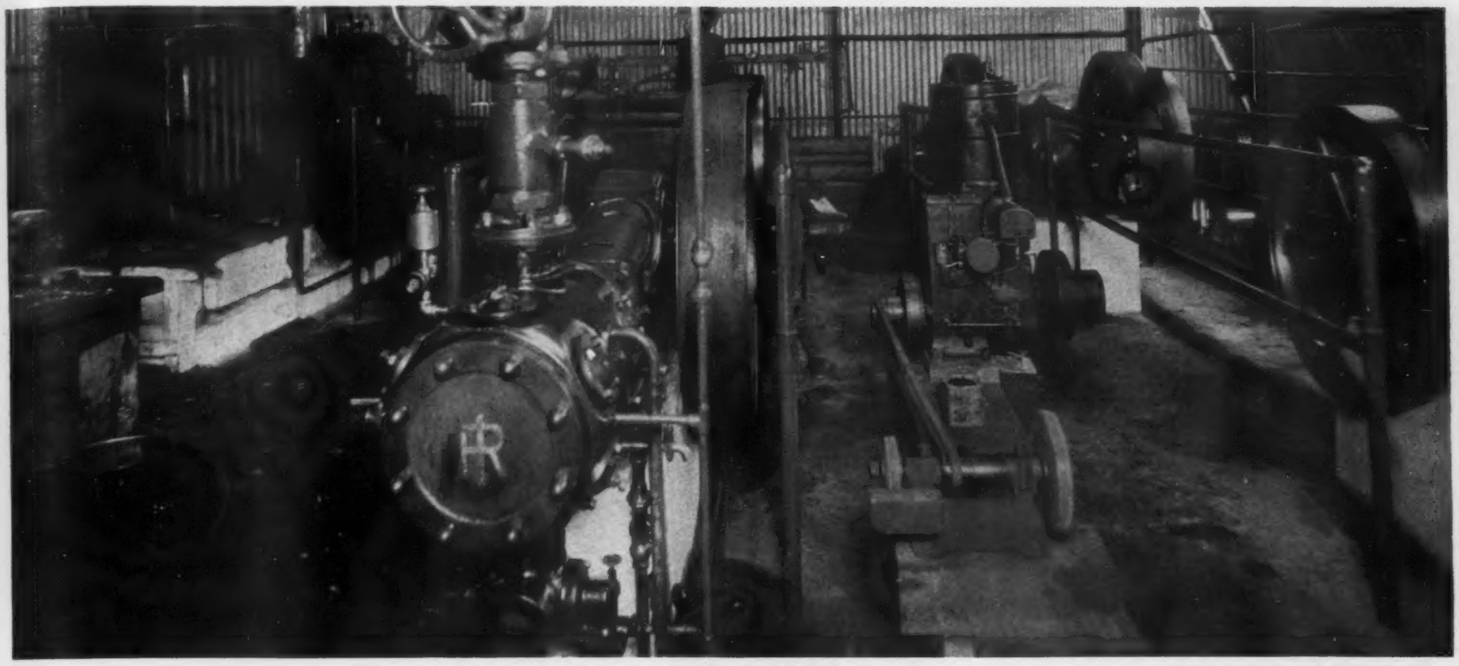
Grout was first injected through the "A" and "K" holes in the invert. Pumping was continued until grout appeared in the next higher set of holes, the "B" and "H", which were spaced 10 feet apart. Connections were then made with these latter holes and grout was pumped into them until it showed in the next higher pair, the "C" and "G" holes, which were spaced 5 feet apart. This procedure was continued, the final injection being made through the three uppermost holes, "D", "E" and "F", after grout from the next lower set appeared in them. As the work continued, supplementary "A" and "K" holes were drilled and grouted as was considered necessary. After the section of tunnel affected had been treated in the manner just outlined, approximately 1,000 feet of invert and 1,650 feet of the remainder of the tunnel section were again gone over.

As the operations progressed, the existence of voids between the brick lining and the enclosing ground was conclusively proved by the extent of the travel of the grout. During the first 70 days of the treatment the average injection into each of 682 holes was 1,600 pounds, but in many holes it was much greater and ranged from 10 tons to as much as






**Top—Grout mixers and steam-driven grout pumps. Center—Cross sections of the tunnel lining showing the locations of the grout holes. Bottom—Side holes were drilled with S-80 drills mounted on carriages.**



**Class ER-1 compressor and other machinery in a corner of the shop.**

30 tons in one case. Where large injections were made the grout moved considerable distances, generally in an upward direction, but also from side to side, passing either below the invert or above the crown. In one instance the travel extended to 22 other holes.

Because occupation of the tunnel on Sundays was limited to five months of the year, cementation operations were suspended in April, 1930, until the following November. During the interim a check of results was made which showed that 2,123 holes, having a total length of 9,752 feet, had been drilled and that 3,016 tons of grout had been injected through 1,830 holes—an average of 1.16 tons per linear foot.

Because of the successful outcome of the work thus far, it was decided to extend the treatment to cover that portion of the tunnel from the Bristol portal to a point about 1$\frac{1}{16}$ miles to the west. At this latter point the marl joins a sandstone rock which, it was believed, would form an effective barrier against the travel of water along the top of the lining. Another contract was accordingly awarded the Francois Cementation Company, and work was resumed on November 2, 1930. This called for further treatment of the part already grouted and for the extension of the cementation to include sections at either side of it. It also included treating the Sea Wall shaft on the English side and the ventilating shaft at Sudbrook on the Welsh side, as the brickwork in both of these had deteriorated to the stage where considerable water leakage was taking place. In winter months this resulted in the formation of icicles, which proved a menace to traffic.

To carry out this program, more equipment was installed. This included two Ingersoll-Rand compressors—a Type POV-2 oil-engine-driven unit, with a capacity of 240 cubic feet per minute, and a steam-driven machine of 386 cubic feet per minute. Two cementation units and four S-80 drifter drills also were provided, and additional lengths of piping were laid in the tunnel. To facilitate getting the equipment in and out of the tunnel on Sundays, a 5-ton crane was installed at the top of the Sea Wall shaft.

Operations in the tunnel were conducted in much the same manner as during the first contract. Holes were drilled at eleven points around the lining instead of nine, the additional two holes being just above the center line on either side. The locations of the holes with respect to the cross section and their designations by letter are shown in an accompanying diagram. The preliminary work consisted of drilling the holes and injecting grout into them in the following sequence:

"B" and "K" on 20-foot centers.
"A" and "L" on 66-foot centers.
"C" and "J" on 20-foot centers.
"E", "F", and "G" on 66-foot centers.
"D" and "H" on 20-foot centers.

Secondary injections were made through intermediate holes in the same order except that the "D" and "H" holes were retreated before the "E," "F," and "G" holes. The final longitudinal spacing of routine holes was: "B" and "K", 20 feet; "A" and "L", 33 feet; "C" and "J", 10 feet; "E", "F", and "G", 33 feet; and "D" and "H", 10 feet. The section of the tunnel affected by the first contract was retreated through intermediate holes spaced in the arch at regular intervals. Wherever damp places developed in the lining, additional holes were drilled and grouted.

Careful records kept during the work showed that, in general, cavities often existed between the lining and the enclosing strata where the tunnel passed through soft formations, but that they seldom were present when the surrounding material was rock. In many instances timber was met immediately behind the brickwork, and in others it was apparent that cavities were due to the fact that spaces between timber and brickwork had not been filled in during construction.

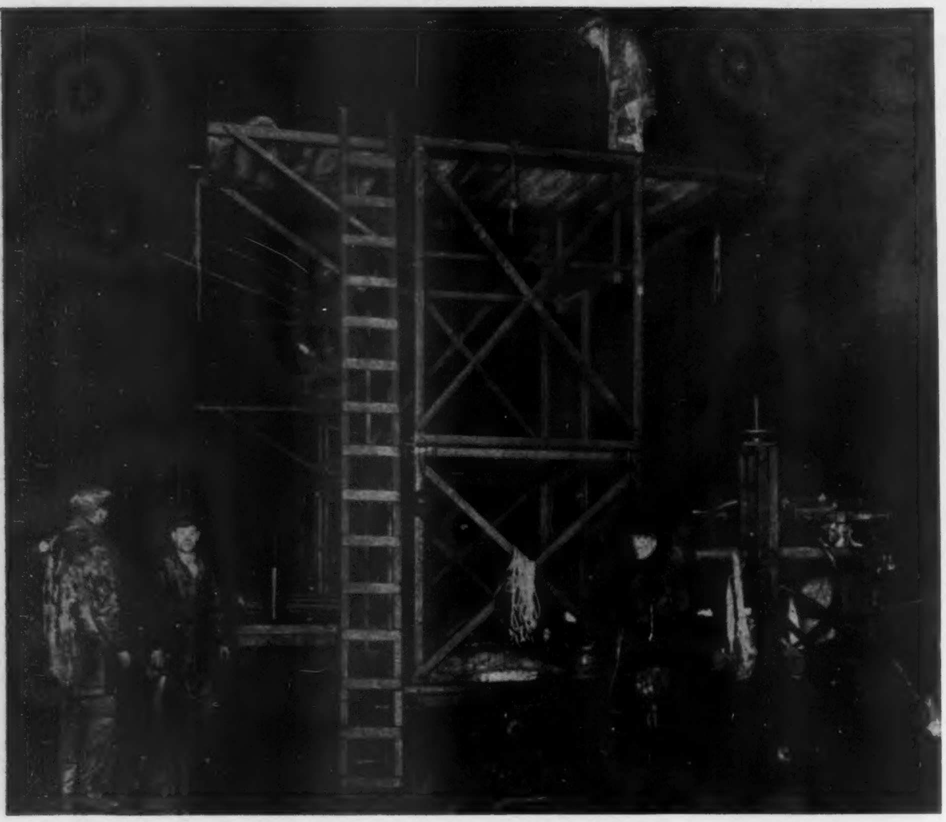
Cases were noted of the drills dropping 6 to 12 inches in holes drilled through the invert where soft material existed below the tunnel. These indications of cavities were confirmed by the amount of grout required in such holes and the extent of the travel of the cement. On the other hand, no large injections in the invert were necessary where rock underlay the tunnel. The conclusion drawn from these facts was that water action and disintegration had produced the cavities in the softer marl.

Of 8,132 tons of grout injected into the tunnel, 676 tons was introduced below the invert, and 400 tons of the latter was used along a stretch of about 1,100 feet underlying the Salmon Pool where trouble from water flows had been experienced in former years.

The grout sometimes traveled as far as 200 to 250 feet from points of injection. Two extensive escapes into zones remote from the tunnel section occurred: one to the surface of the Sea Wall road, the other into the river bed. To guard against further migrations from the river, the bed of the stream was patrolled at low-water periods while grouting was underway, and periodical fluorescent injections were made so that escaping cement might be detected by coloration of the water.

The Sea Wall and Sudbrook ventilating shafts were treated concurrently with the tunnel proper. Work was carried on from staging maneuvered from above by cranes, which also handled men and materials. To clear the shafts of obstructions so as not to interfere with the ventilation of the tunnel, the staging was removed after each of the 6-hour working periods on Sundays, to which the contractor was restricted.

The Sea Wall shaft is 18 feet in diameter and 78 feet deep. The Sudbrook shaft, which houses the main fan on the ventilating sys-



**The two types of drill carriages used. Holes in the upper section of the tunnel were drilled from the larger structure, which also served for the cementation and calking operations.**

tem, is 29 feet in diameter and 175 feet deep. Both are lined with brick walls 18 inches thick. Injections in each case commenced at the bottom and were carried progressively upward, the distribution of holes being governed largely by the locations of water feeders and moist places. In the Sea Wall shaft, 17 holes, totaling 68 feet in length, were drilled and 93 tons of cement injected. The first injections in the Sudbrook shaft showed grout leakages along the tunnel line as far away as 528 feet, and water diversions to points up to 675 feet distant. To build up a barrier of cement around the base of the shaft, intermittent injections were made through the lower holes, and, finally, chemicals were introduced to quicken the process of hardening. This proved effective, and the cement started to rise around the shaft upon further introductions. Eighty-four holes, having an aggregate length of 377 feet, were drilled there and 477 tons of cement injected.

As a result of this cementation it is believed that the tunnel has been rendered fit for many more years of service without further maintenance work. It is certain that large, open joints, extending in some cases to the surface, have been filled so as virtually to prevent the travel of water through them. The residual leakage, too, is now so small as to obviate the probability of the formation of further large voids in the surrounding strata as a consequence of flows. Accordingly, it is felt that the chance of the river water breaking through has become negligible.

Acknowledgment is made to the Great Western Railway Company of London and to its chief engineer, Mr. Raymond Carpmael, M.I.C.E., M.I.M.E., for the information on which the foregoing article is based and for photographs and drawings. Certain drawings also are reproduced through the courtesy of the Institution of Civil Engineers of England.

## COMPRESSED AIR "BROOMS" REVEAL HIDDEN DIAMONDS

COMPRESSED air "sweepers" are being used with satisfactory results in one of the open-cut diamond mines in South Africa to clean the bedrock and thus make certain that no gems have been overlooked in the fine material which cannot be removed by other means. Equipment of this kind is in use at the property of the Cape Coast Exploration at Kleinzee, on the western coast of the continent and not far from its southern tip.

**Scouring base rock with the air-operated "broom" for hidden diamonds.**

The diamonds are found in gravel deposits resting on rock. Under traditionally employed methods, the upper portions of the gravel were removed by suitable means of excavation, after which the bedrock was swept with wire brooms. It was found, however, that because of the rough and irregular surface of the rock it was impossible to remove all of the fines in this manner. Since the cracks and crevices often conceal small but very rich patches of gravel, a means of thoroughly "scrubbing" the surface and freeing adhering material was sought. The "sweepers" or blowers now employed were devised in conjunction with Ingersoll-Rand Company of South Africa, Ltd.

One of these air brooms is shown in use in the accompanying illustration. In effect, it is simply a pipe through which there is passed a jet of compressed air, the end of the pipe being formed so as to direct the air as desired. The pipe fits into the end of a compressed-air delivery hose and is taken in hand by the operator who plays the air stream upon the rock as if he were washing the surface with a hose and water. In fact, the result is much the same as that obtained by directing a stream of water upon the rock; but it is accomplished without the attendant wet conditions.

A number of types of outlets for the air has been tried. The two most suitable forms are a flat ¾-inch nozzle with a ⅛-inch slot, and a fan-shaped jet, 6 inches wide, with 1/16-inch perforations drilled about three-quarters of an inch apart. The slotted jet is employed for cleaning out deep cracks and crevices, and the fan-shaped type for scouring the more or less smooth surfaces. The slotted form can be inserted into the wider cracks and openings and used to loosen the gravel by gouging as well as by blowing. On ordinary rock surfaces, the jet is held about a foot back from the point being cleaned.

This new method has greatly increased the efficiency of bedrock cleaning, as it gives positive assurance that no rich diamondiferous gravel has been overlooked. The air supply comes from the same compressor that provides air for the "Jackhamers" used in breaking up consolidated gravel.

The air jets have been employed in the removal of large quantities of loosened material with good results; but as this work can be accomplished by other means at a lower cost, the use of the "sweepers" is usually limited to the scrubbing process.

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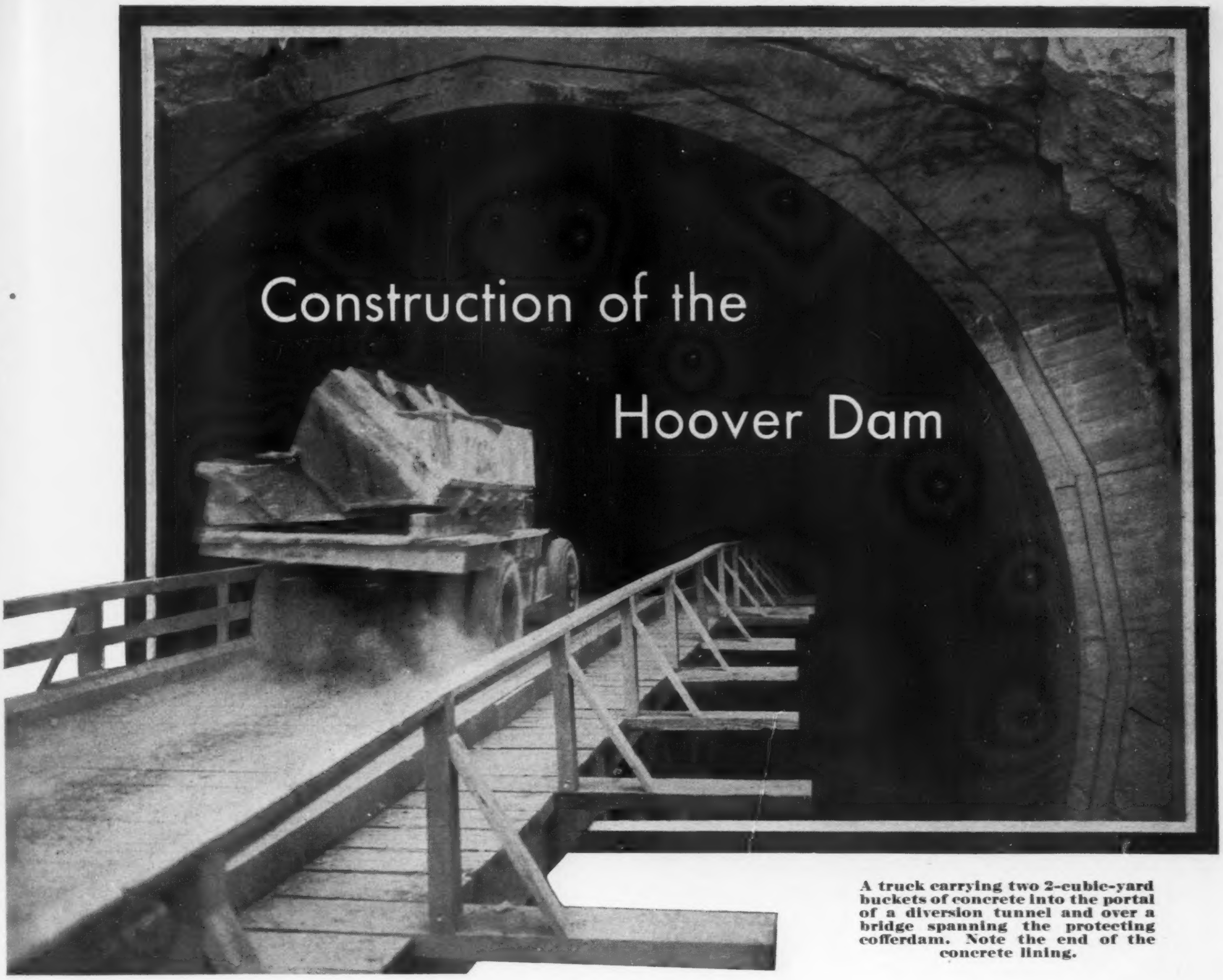
What is believed to be the smallest complete ball bearing ever manufactured has been placed on the market by the Fafnir Bearing Company of New Britain, Conn. It has been designed for instruments and for other delicate applications, and carries ⅛ inch balls. The bearing has an outside diameter of ½ inch, a hole ⅛ inch in diameter, and is less than 3/16 inch wide.

# Construction of the Hoover Dam



A truck carrying two 2-cubic-yard buckets of concrete into the portal of a diversion tunnel and over a bridge spanning the protecting cofferdam. Note the end of the concrete lining.

## *Lining of the Diversion Tunnels with Concrete**

**C. H. VIVIAN**

THE four diversion tunnels which will by-pass the Colorado River through the walls of Black Canyon while the Hoover Dam is being rooted in solid rock underlying the stream bed are being lined with concrete to insure their stability, strength, and carrying capacity while in service. Concreting operations have been in progress for more than eight months, and on November 1 were approximately 74 per cent completed. Just as the driving of these bores constitutes a new chapter in the annals of construction because of their magnitude, so does the application of concrete to their surfaces involve the doing of this particular thing on a bigger scale than it was ever done before. For the most part, standard practices and methods are being followed; but the element of hugeness, alone, is sufficient to make the work unique and to clothe it with interest. Nearly 2,000 tons of steel was used in making up the lining forms; and the cost of the equipment especially prepared for the work was approximately $325,000.

By way of refreshing the reader's memory, we should perhaps set down that there are four diversion tunnels—two on either side of the river. They range in lengths from 3,561 feet to 4,300 feet, and they total 15,909 feet, or about 3.1 miles. They are circular in cross section and were excavated to 56 feet in diameter. They are being lined with an average thickness of 3 feet of concrete, which will give them a finished section of 50 feet.

It is estimated that 394,000 cubic yards of concrete will be required for the lining operations. This would build about 135 miles of paved roadway 18 feet wide and 10 inches thick. Of this quantity approximately 77 per cent, or 303,000 cubic yards, will be paid for at the unit bid price of $11 per cubic yard. The remaining 91,000 cubic yards will have to be placed because of the overbreak of rock resulting from the impossibility of excavating evenly along the desired line, and is classed as nonpay yardage.

For purposes of concreting, the circular tunnel section is divided into three parts. The lower 74° comprises the invert, which is poured first. Above it, on either side, are side-wall portions of 88° each or 176° combined, and these are poured second. Last of all, the remaining roof or arch section of 110° is placed. Disregarding overbreak, it requires approximately 18.5 cubic yards of concrete for each linear foot of lining. This yardage is made up as follows: invert, 3.8; sides, 9; arch, 5.7.

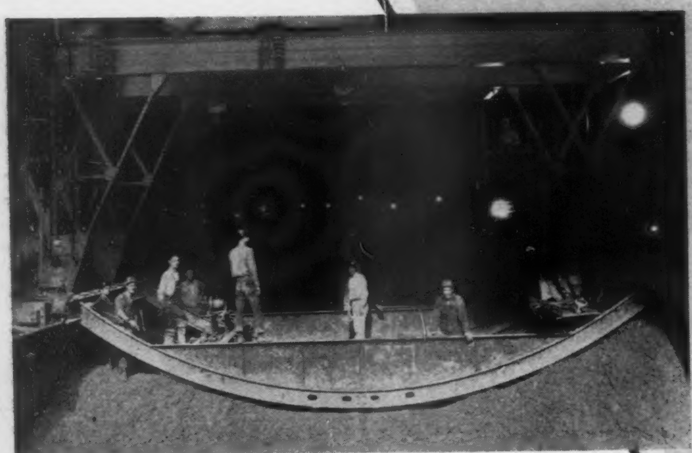
Each of the component sections required to form a complete cylinder of lining is of the same length, so that a complete transverse construction joint is secured where such a cylinder abuts another one. The length of each section is 40 feet, except in those portions of the two outer tunnels which will later be used as spillways, where it is 26 feet 8 inches. Keyways are provided in all joints, both transverse and longitudinal, to knit the lining structure together as strongly as possible.

The concreting was started at the upstream

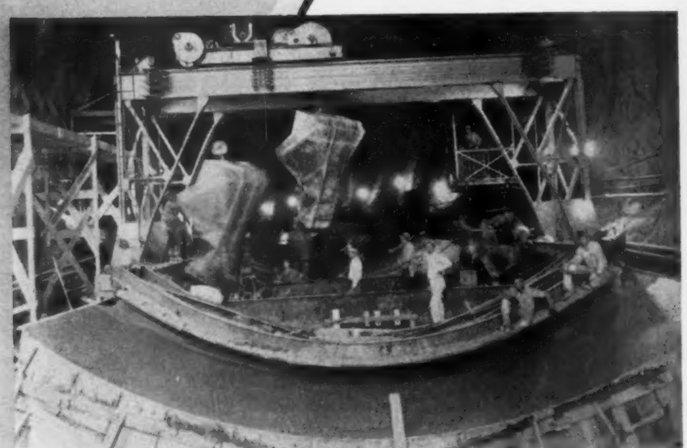
*Twelfth of a series of articles on the Colorado River and the building of Hoover Dam.*

These pictures show progressive steps in the pouring of the invert or lower section of the concrete lining.

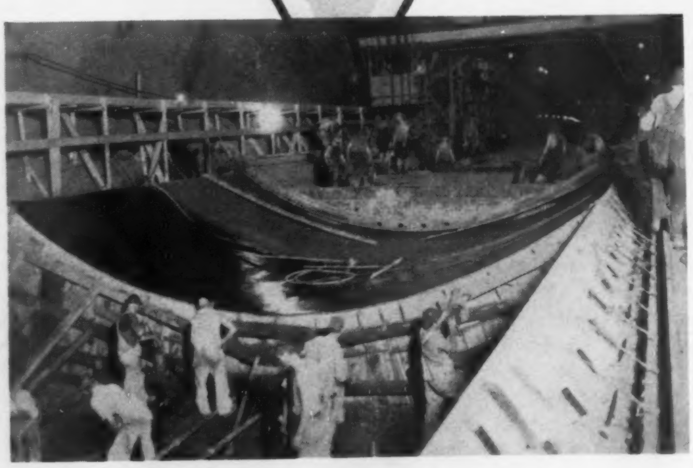
Left—Forms set up between longitudinal concrete risers placed at either side as bases for the gantry-crane rails.



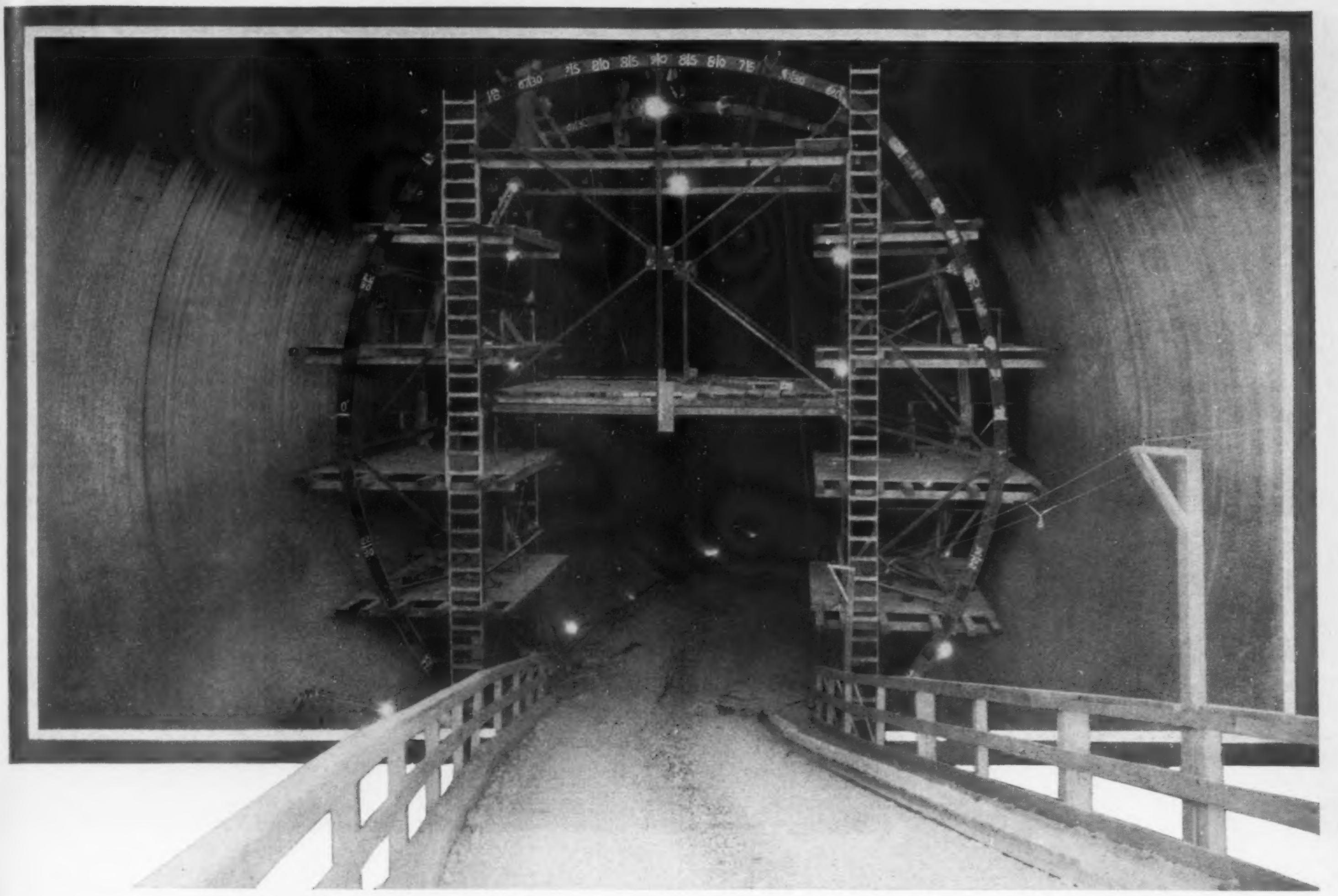
The concrete poured by the gantry crane is mechanically troweled to the correct surface curvature by a movable template.



A section of the invert has been completed and the template moved ahead. The crane is handling two concrete buckets.



Workmen are removing the forms from a finished section of the invert.



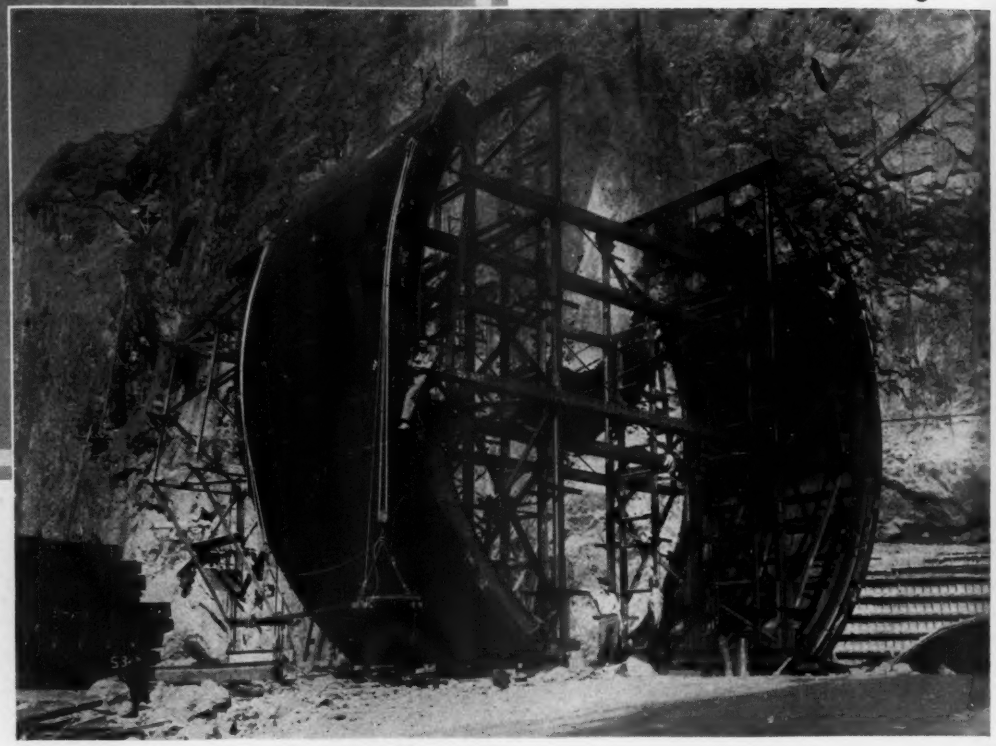
**Drilling holes in the arch for low-pressure grouting. Jumbos such as this, which were used for trimming the tunnel to line during excavating, have been adapted for grout-hole drilling. Sixteen N-75 drifter drills are mounted on this carriage.**

portals and carried progressively toward the downstream ends of the tunnels. A minor departure from this practice has been to start the invert pouring several hundred feet ahead and then work back toward the finished portion. All concrete is mixed at Lomix, the low-level mixing plant located a short distance upstream from the tunnel inlets on the Nevada side of the river. Two types of conveyances are used for moving the concrete from the plant to the pouring sites. Where the pouring must be done with the aid of gantry cranes, the material is transported on trucks in 2-cubic-yard bottom-dump steel buckets. Eleven trucks which had previously been used for hauling muck from the tunnels were converted from dump types to flat-bed bodies for this service. Each truck hauls two buckets at a time—a total of 4 cubic yards of concrete. Where the concrete can be poured directly into forms or into chutes leading to hoppers from which buckets can be filled as needed, the transportation is effected in Rex 4½-cubic-yard agitator mixers mounted on trucks. Fourteen such units were employed at the height of concreting operations. Trucks cross the river to and from the Arizona tunnels on a suspension bridge which was used to handle muck during the excavating of the bores. Concrete arch cofferdams have been built around each portal to keep water out of the tunnels during floods and are flanked on the river side by rock fills. To provide a means of passing over these barriers, wooden trestles were erected connecting with ramps leading down to the tunnel floor. During the lining of sections near the inlets, concrete was hauled to the portals in agitators and then chuted below to a steel hopper from which steel buckets were filled and trucked to points of use.

The first operation in preparing to pour the invert is the construction of two longitudinal concrete strips to serve as rail bases for the gantry crane. The inside face of each of these benches is 15 feet 9½ inches from the center line of the tunnel, and the top of this inside face is 24 inches from the point which will mark the finished surface of the lining. This interval, which corresponds to the minimum thickness of lining allowable under the specifications, is later filled and the track bases become integral parts of the lining. Timbers 6x12 inches are laid on each of these concrete strips, and 90-pound rails are spiked to them. The 10-ton electrically operated gantry crane has a maximum speed of 300 feet per minute along these rails. Its transverse bridge is equipped with two hooks, each with a lifting capacity of 5 tons and a hoisting speed of 100 feet per minute. Four such cranes have been in service—one in each tunnel.

After the rail foundations are in place, steel side forms for the invert are bolted to them. These forms are 2 feet high and are made up in sections of 10 feet. They are composed of 10-gauge steel plate supported by 2-inch angle irons at the top and by 2x3-inch stiffeners. Transverse forms of steel, shaped to conform to the radius of the invert section, are bolted to the longitudinal forms and also braced against the tunnel floor. They are 2 feet high, and the space between their lower edges and the tunnel floor is bulkheaded with 2-inch timbers. These transverse forms are spaced at intervals of either 26 feet 8 inches or 40 feet.

The invert surface is mechanically made to conform to the desired curvature by means of a template. The framework for this device consists of two transverse I-beams, spaced about 11 feet apart and connected at their ends by steel members. This frame runs along the tunnel on car wheels, the upper flanges of the longitudinal plates of the concrete invert forms being their tracks. The beams are shaped to conform to the curvature of the tunnel radius. Their lower inside flanges form tracks for wheels which support two cross members, each some 11 feet long and 4 feet wide and consisting of two decks. The bottom deck is a screed plate, which is also shaped to the curvature of the finished tunnel section. The two screeds are independently operated by hand winches on their upper decks. These winches control cables which pass over sheaves and fasten to the end pieces connecting the two I-beams. When concreting of an invert section starts, the two screeds are together



**Right—A section of the massive side-wall forms being assembled on the beach in Black Canyon. Above—Close view of a portion of a form in position for pouring concrete.**

in the center of the tunnel line. The gantry crane takes up two buckets of concrete from a nearby truck and moves them to the form. There they are dumped, one on either side of the screeds, by the manual operation of a hand wheel which controls their gates. The concrete thus deposited is puddled into place by workmen. When the concrete has been built up sufficiently high, the screeds are moved outward, toward the tunnel side walls, by means of the winches. By repetition of this procedure, until the edges of the form are reached, the required concave surface is obtained, the screeds acting in effect like huge inanimate trowels. The finishing touches are applied by workmen stationed on a movable timber platform suspended just above the concrete and supported between two curved I-beams mounted on flanged wheels which run on the same rails as the gantry crane. The screed framework can be jacked up sufficiently to obtain clearance and thus be moved manually to its next position. Moves of any considerable distance are made with the aid of the gantry crane. After a section of invert has been finished, a roadway for trucks is made by leveling it up with about 3 feet of sand.

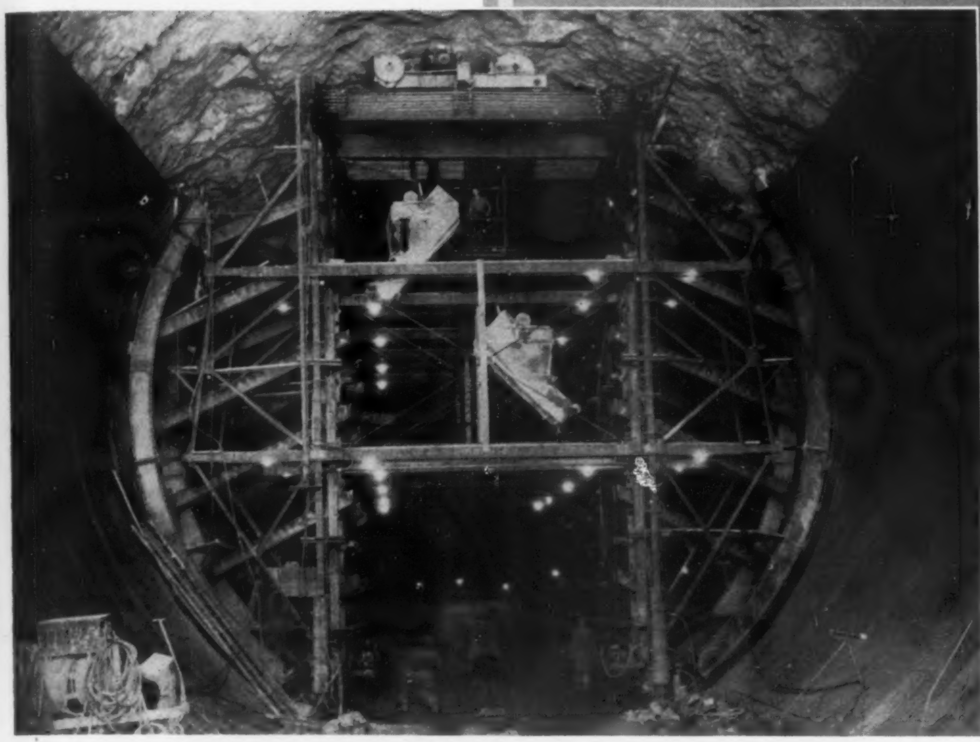
The side-wall and arch sections of the lining are poured behind special forms. Because of the great size of the tunnels, standard forms could not be utilized. Those in use were designed by Six Companies Inc. and made up to their specifications by the Consolidated Steel Corporation of Los Angeles.

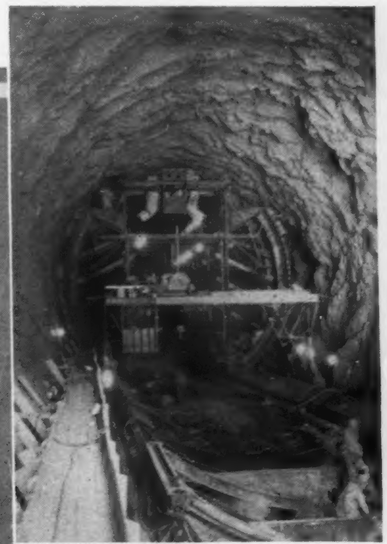
The pouring of the side-wall sections must necessarily follow some little time after the invert placing, as this lower portion of the lining is utilized not only as a haulageway for the concrete used later but also as a means of support for the forms which receive it. The first step is to pour two concrete strips 18 inches wide running lengthwise of the tunnel and resting on the invert. Ninety-pound rails are laid on these, each rail being 11½ feet from the center line of the tunnel. This 23-foot-gauge track constitutes the runway for the side-wall jumbo, a mammoth structural-steel framework 80 feet long and 50 feet high and weighing 385 tons. It supports the wall forms composed of ¼-inch steel plate. To render it usable on curves, where the two opposing walls are of different lengths, the jumbo is made up in five sections, three of 20 feet and two of 10 feet. Wooden panels are built up between the steel panels where a gap results in rounding a curve.

The jumbo is completely equipped for handling concrete and pouring it where desired. At its top is a 5-ton, electrically operated bridge crane which can travel longitudinally at the rate of 300 feet per minute on 50-pound rails. Its transverse traveler can move at a speed of 125 feet per minute, and its two steel hooks have hoisting speeds of 100 feet per minute. Concrete is elevated in 2-cubic-yard buckets and poured into chutes of rectangular section which lead to the faces of the forms. These chutes are of ¼-inch steel, reinforced by 2-inch angle irons. They are 30 inches wide, 12 inches deep, and from 8 to 16 feet long, and there are six longitudinal rows of them spaced from 4 to 6 feet vertically at the form faces. The openings in the form faces to which the chutes lead are fitted with 12x24-inch steel doors or gates which can be manually closed and bolted.

In addition to the six rows of simple chutes there is a row at the top of each form of what are designated as "coffin" or "bathtub" chutes. Each is hinged at the form line, which permits lowering the end toward the center of the tunnel while the depressed chute is being filled and then raising the loaded end to give the chute sufficient slope so that the concrete will flow to the form by gravity. These chutes are raised and lowered by a cable which passes over sheaves and which is operated by an Ingersoll-Rand Size HU "Utility" hoist, two of which are installed at the base of the jumbo. The upper 4 feet of the side-wall sections is poured by this means. A series of screw jacks and ratchets is provided for adjusting the wall forms for pouring, for releasing them from the finished concrete faces, and for providing for the distribution of the hydrostatic pressure of green concrete.

Pouring is, of course, started through the lowest row of chutes and carried progressively upward. The two opposite walls of a section are poured simultaneously, and individual sections of either 26⅔ or 40 feet in length are completed to the top of the forms before adjoining ones are started. To provide these shorter sections while using an 80-foot form, a timber bulkhead is erected at the proper





**Left—Side-wall forms in position, with two buckets of concrete being elevated for pouring into the chutes. Above—Side-wall forms being made ready for use.**

point. This is framed so as to leave a keyway in the end of the section 10 inches wide and 1½ inches deep. A round iron bar, 3 inches in diameter, is secured over the entrance to each chute. In pouring, the crane operator maneuvers each bucket of concrete into such a position that hooks on the bucket gate are directly above this bar. Lowering the bucket trips open the gate, and the concrete pours into the chute. The bucket is then disengaged from the bar, lowered to the truck that brought it, and the second bucket is raised from the truck bed and poured in a similar manner into the corresponding chute on the opposite side of the form. Behind each form, in the 3-foot space between the steel plate and the rock wall of the tunnel, are from five to seven men, who puddle the concrete into place, and an inspector. When a section has been built up to the level of the row of chutes through which the pouring has been done, the gates are closed over those openings and bolted securely, thus making them integral parts of the form for subsequent pouring. Delivery of concrete is then started through the next higher set of chutes, and this procedure is repeated until the section has been completed to the top of the form. The final operation is to form a keyway approximately 10 inches wide and 2 inches deep on top of the section, where the arch will later rest.

It requires about 50 hours of elapsed time to complete an 80-foot section of side wall, which includes both sides of the tunnel, and to set up for the next one. The pouring itself consumes about 24 hours. The forms are left in place ten hours longer. The timber bulkhead at the end of the form, which does not bear against a previously formed section, is then removed; jacks and ratchets are loosened; and the jumbo is advanced to its next position by means of a block and tackle secured to the rails ahead and operated by the compressed-air hoists at the base of the form structure.

The arch or top section of the tunnel is lined pneumatically. The structural-steel jumbo that supports the forms and carries all essential apparatus is really a 3-part structure, all the units of which are mounted on flanged wheels that run on the steel rails used by the side-wall jumbo. The three parts of this jumbo are: an arch-form support, a concrete-gun carriage, and a pipe carriage. The general features of the arch-form support, and the manner in which it holds the steel plate or skin on the top of which the concrete is placed, are clearly shown in one of the accompanying pictures. The forms are moved into position for pouring or withdrawn from the finished concrete face by means of screw jacks. The framework for the gun carriage is approximately 46 feet high and 45 feet long and it is run along its track by a 25-hp. motor at a maximum speed of 100 feet per minute when going forward and 20 feet per minute in the reverse direction. On each side, at the base, is mounted a 2-cubic-yard Hackley concrete placement gun, with hopper. Overhead, near the top of the framework, are two air receivers, one on either side, that supply the surge of compressed air necessary for discharging each batch of concrete. Air is piped into the tunnels from the established distribution systems.

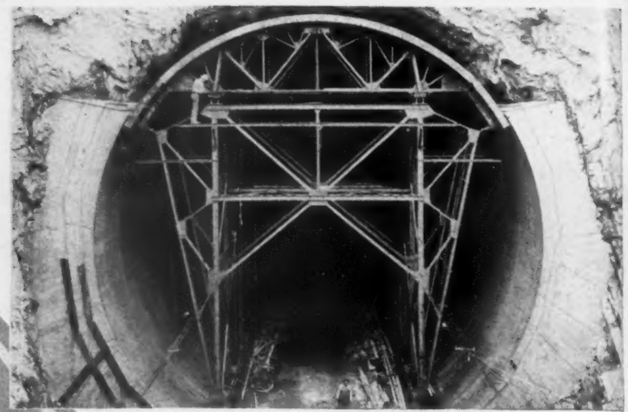
Next to the gun carriage is the pipe carriage which supports the 6-inch wrought-iron pipe through which the concrete is conveyed to the forms. The traveler is stationed between the arch-form jumbo and the pipe carriage.

An electric double-drum hoist on the gun carriage lifts a 4½-cubic-yard agitator of concrete from a truck and discharges it into the hopper of either of the guns. The batch is then shot upward and forward through the delivery pipe and its rubber-hose connections to the arch form ahead. Placing is started at the end of the form farthest from the concrete guns; and the equipment is moved rearward as the work progresses. Construction joints with keyways are secured at intervals of 26⅔ or 40 feet by placing bulkheads.

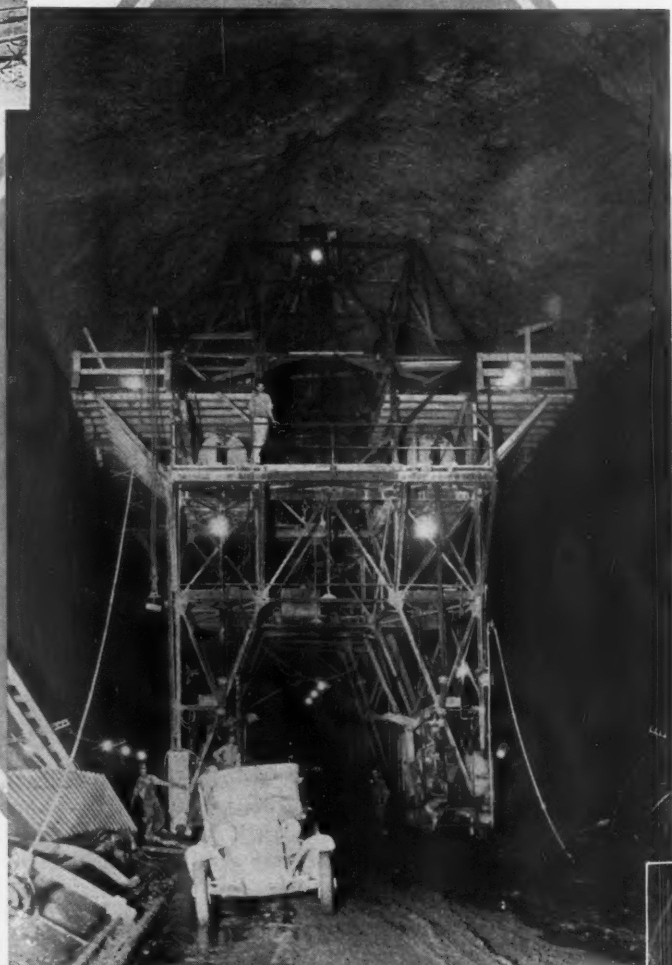
The concrete was first cured by sprinkling the surfaces with jet sprays as soon as the forms were removed and keeping them continuously wet for fourteen days. River water was pumped from sumps near the tunnel portals by Cameron Type HV centrifugal pumps. Since May all curing has been done by applying a Hunt process asphaltic paving coat. The spraying is done with compressed air.

Specifications for concrete in the tunnel lining are very rigid, and insistence is placed on each batch being as nearly identical as it is possible to make it with the others of a like mix. The Bureau of Reclamation main-

**Arch jumbo under construction. Human ants may be discerned at several points.**



**Arch form being set up at a tunnel portal. Invert and side-wall lining sections are in place.**



**Left—Concrete-gun carriage used in placing the arch section of the lining.**

**Below—Filling a bucket with concrete from an agitator truck. Side-wall pouring chutes are at either side.**

**Right—Interior of a tunnel with invert and side-wall sections of the lining completed.**

tains a laboratory adjacent to the mixing plant, and a large staff of technicians and inspectors is in constant attendance. Cylinders are made regularly throughout the day, and are tested in the usual manner.

Concrete for invert and side-wall sections contains 1 part cement, 2.1 parts sand, and 4.7 parts gravel. A 4-cubic-yard batch weighs 16,600 pounds, distributed as follows: cement, 2,000 pounds; sand, 4,200 pounds; gravel, 9,400 pounds; and water, 1,000 pounds. Thirty-six per cent of the gravel, or 3,380 pounds, is of the coarse grade, which ranges from 1½ to 3 inches; 32 per cent, or 3,010 pounds, is of the intermediate size, ¾ inch to 1½ inches; and 32 per cent, or 3,010 pounds, is of the fine size, ¼ to ¾ inch.

The allowable slump in the invert and side-wall concrete is from 3 to 4 inches. The slump of concrete, it may be explained, is the measure of its consistency. The standard method of determining slump consists of forming a cone—12 inches high, 8 inches in diameter at the base, and 4 inches at the top—by filling a mold with four layers of concrete and tamping each layer 25 times with a ⅝-inch rod which is bullet pointed at the end. The mold is removed immediately after being filled. After the concrete has settled, the amount of sag or slump from its original height is measured.

The largest size of gravel, 1½ to 3 inches, is omitted from concrete for the arch section, for which the following ratio is specified: 1 part cement, 2.5 parts sand, and 4.3 parts gravel. By weight, a 4-cubic-yard batch contains 2,000 pounds of cement, 5,000 pounds of sand, and 8,600 pounds of gravel. The gravel is 60 per cent of intermediate size and 40 per cent of fine size. Sufficient water is added to the concrete to give it a 6- or 7-inch slump.

After the tunnels have served their purpose—that of diverting the water around the dam site, they will be used for other purposes. The two farthest from the river, Nos. 1 and 4, will become spillway outlets. To accomplish this, each of the tunnels will be plugged with reinforced concrete about midway of its length for a distance of 396 feet. This plug will be just upstream from the entrance of each of the inclined spillway tunnels, which will extend to the surface and emerge at the approximate level of the top of the dam.

Each of the two inside tunnels, Nos. 2 and 3, will become a penstock tunnel for a portion of its length and will house a 30-foot-diameter steel penstock pipe. To convert these bores for this service, upper and lower concrete plugs will be placed in each of them. In order that irrigation water may be passed to the Blythe, Yuma, and Imperial valleys during the period that the reservoir is being filled to the level of the intake towers—approximately 300 feet, it is expected that the heavy slide gates will be operated through these upstream plugs. Trash-rack structures will be built at their intake portals. Each of the downstream plugs will later contain six 72-inch needle valves, which will be connected with the penstocks, and the upstream gates will be plugged. At the downstream portals, 50x35-foot stoney gates will be built.

The two outside, or spillway, tunnels will be open at their lower ends, but their intake portals will be closed off with steel bulkhead gates, each of about 1,100 tons weight.

When the tunnels were driven, excavations were also made for the tunnel plugs, which are approximately 12 to 16 feet larger in diameter than the 56-foot tunnel bores. They are irregular in shape and resemble in cross section three wedges linked together endwise. The specifications provide that the tunnel-plug excavations must be lined with 3 feet of concrete, corresponding to the rest of the tunnel lining, but that they must likewise present smooth surfaces continuous with the standard 50-foot lined sections during the period of diversion. Six Companies Inc. were given the alternative of filling in the annular spaces with concrete or of erecting timber falsework in them. As it would have been necessary to remove the concrete in order to install the plugs, the latter method was chosen; and timber panels have been constructed which will present smooth center surfaces to the water and which are fastened to the concrete lining with anchor bolts in such a manner that they can readily be taken down.

**Chuting concrete down into a tunnel from the top of a cofferdam at one of the portals.**

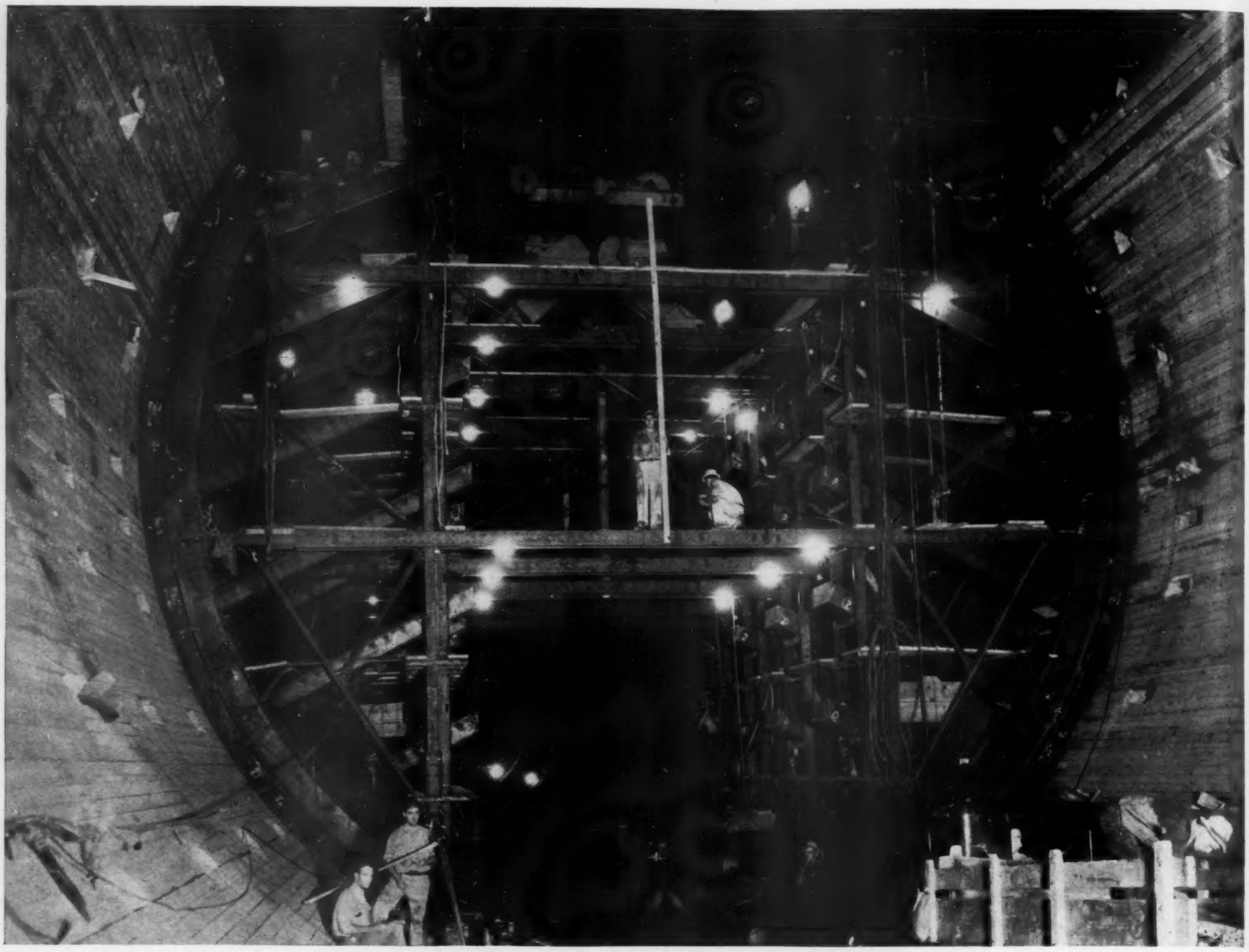
These forms are very intricate, and the designing of them called for the exercise of much engineering resource and ingenuity. A large concrete surface was poured to serve as a drawing board on which to lay out the measurements of the hundreds of different shapes of panels required. A small sawmill and a crew of 25 carpenters were engaged for several months in making them up. After being cut to specific sizes and shapes, all timber sections were numbered so that they might be assembled in proper order and position in the tunnels. They were then stored in rows on the desert to await use. The average size of the timber pads is about 20 feet in length and from 4 to 6 feet in their other dimension. As many as 425 different shapes and sizes were required for one structure. When one of these forms is being installed, the steel form for the arch or side-wall section is moved into position. The timber pads are then built up around it; bolted in four directions; and anchored in the concrete lining of the larger section, as the concrete is poured by means of chutes which pass through both the steel and the wood forms.

Specifications call for both low-pressure and high-pressure grouting of the tunnels. Low-pressure grouting, which is done only in the arch section, is largely for the purpose of filling voids which may occur between the lining and the rock, and to compensate for any shrinkage which may have occurred. Holes for introduction of the grout are drilled with Ingersoll-Rand N-75 drifter drills, sixteen of which are mounted on a modification of the steel framework which was used in trimming the tunnels to line. Three holes, each 2 inches in diameter, are driven in the arch section—one in the center, and two at 45° angles from the perpendicular, as well as special holes to overbreak points. A set of these holes is drilled every 20 feet along the tunnel line.

Grout, consisting of neat cement and water, is applied at from 50 to 100 pounds pressure by means of a duplex, air-driven, piston grout pump which is mounted on a truck together with a mixer. The truck also hauls a trailer loaded with bags of cement. Water is obtained from pipe connections on the line which extends throughout the length of the tunnels.

High-pressure grouting will be done in certain portions of the tunnels at the direction of Bureau of Reclamation engineers. It is expected that the holes for this purpose will extend 20 to 30 feet into the rock and that grout will be forced into them under a pressure of from 300 to 500 pounds. It is believed that not much grout will be required owing to the dense, compact character of the rock and the absence of cleavage and shear planes. These high-pressure holes will be staggered radially, eight in a ring, around the tunnel, and grout will be applied merely as an added precautionary measure to strengthen the lining in zones which will be subjected to particularly heavy stresses and high velocities when the tunnels are in service.

Lining operations were started in Tunnel No. 3 on March 16, 1932, and in the other



**Placing temporary timber lining, which conforms to the 50-foot finished concrete lining of other sections, in an enlarged part of the tunnel that will later be plugged with concrete. This view shows details of the side-wall lining forms.**

bores, as follows: No. 2, March 29; No. 4, April 7; and No. 1, August 3. The following table shows the quantity of concrete placed, in cubic yards, by months:

| | Pay Yardage | | | |
|---|---|---|---|---|
| | Invert | Side | Arch | Total |
| March.... | 1,064 | .... | .... | 1,064 |
| April...... | 8,664 | 405 | .... | 9,069 |
| May...... | 4,161 | 15,210 | .... | 19,371 |
| June...... | 11,518 | 16,816 | 4,102 | 32,436 |
| July...... | 14,440 | 27,243 | 10,966 | 52,649 |
| August.... | 8,409 | 27,461 | 14,873 | 50,743 |
| September. | 1,280 | 14,269 | 17,803 | 33,352 |
| October... | 3,210 | 13,796 | 9,655 | 26,661 |
| Total..... | 52,746 | 115,200 | 57,399 | 225,345 |
| | Gross Yardage Placed | | | |
| | 77,771 | 143,862 | 69,369 | 291,002 |

During August, a typical month, the production of the concrete mixing plant averaged 171 four-cubic-yard batches per shift, or 2,052 cubic yards every 24 hours. The two best days of tunnel lining thus far were June 13 and 14, when 2,646 and 2,750 cubic yards, respectively, were placed during a 24-hour period. The average of concrete poured per day has been about 1,400 cubic yards, of which 1,080 was pay yardage.

The following tabulation shows the percentages of the various sections of lining that had been placed up to November 1.

| Tunnel | Invert | Sides | Arch |
|---|---|---|---|
| No. 1 | 55% | 32% | 5% |
| No. 2 | 100 | 92 | 76 |
| No. 3 | 100 | 100 | 86 |
| No. 4 | 100 | 100 | 96 |

About 900 men, working 300 per shift, were engaged in various capacities in connection with the tunnel lining when work was at its height. On a typical day, 916 men were occupied as follows: cleaning up invert and side walls, 142; grouting, 77; placing concrete, 199; trucking concrete, 53; mixing plant and water plant, 43; erecting wood forms, 70; erecting tunnel-plug forms, 63; building wood forms in shop, 27; moving invert, side, and arch forms, 112; trucking materials, 8; miscellaneous, 122.

Tunnels Nos. 3 and 4, both on the Arizona side of the river, were completed early in November, and on November 13 and 14 the stream was diverted through them. The first water entered Tunnel No. 4 after a blast had cleared a channel through the cofferdam in front of the portal. A diversion dam was then hastily constructed across the canyon just downstream from the tunnel intakes. This was accomplished by dumping trucks of rock from a trestle bridge which spans the river there. It required 30 hours, during which period an average of four truckloads a minute was deposited, to complete this barrier. A similar dam was thrown across the canyon just upstream from the tunnel outlets to keep the water discharging from the tunnels from backing up in the stream bed. These rock dams are temporary, as cofferdams, higher and tighter, will be constructed to uncover approximately 3,800 feet of the river bed until excavations have been made and the dam footings placed.

The diversion of the river ends the preliminary or preparatory stage of construction. The work at the dam site proper can now proceed unhampered. If all goes according to schedule, the excavations will be ready to receive the first concrete next summer.

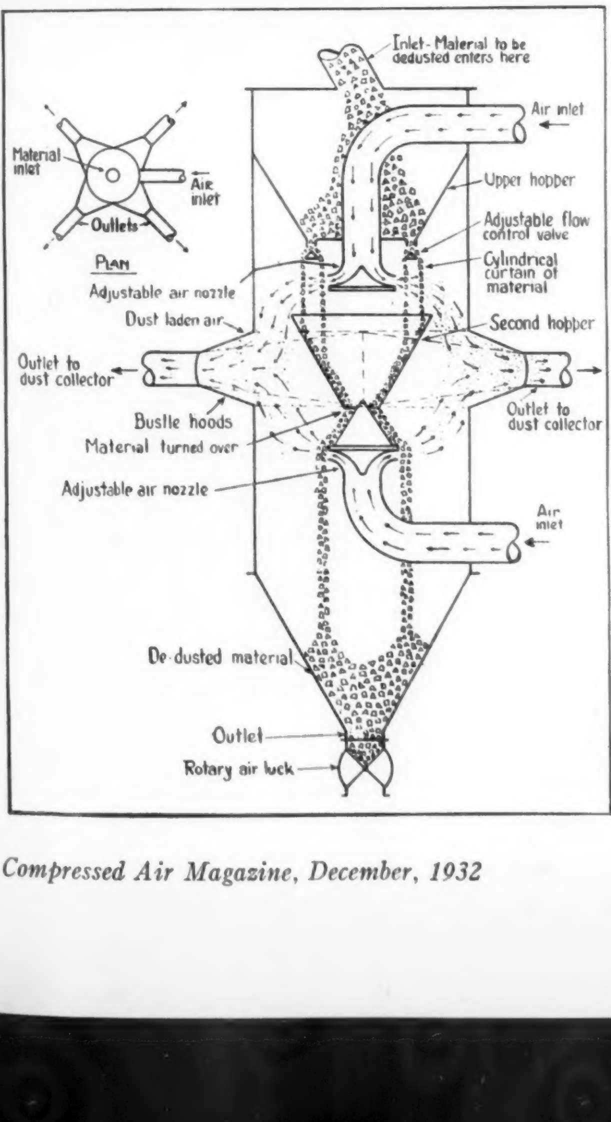
## DRY-CLEANING MACHINE FOR SAND AND GRAVEL

FOR the purpose of removing undesirable dust and fines from gravel, Blaw-Knox Company, Pittsburgh, Pa., has designed and built an entirely new piece of equipment called the De-Duster. This machine handles material from minus 1 inch down; and the cleaning is done by low-pressure air.

As the accompanying sketch shows, the gravel to be "de-dusted" is run into a hopper in the top of the machine. From there it flows through circular feed slots over adjustable flow-control valves that divide the material into two cylindrical curtains dropping in opposite directions. At this stage the gravel curtains are acted upon by streams of air admitted from above and issuing from a 2-way adjustable nozzle—the heavier particles falling into a second hopper immediately below while the lighter fines are blown through a bustle hood, surrounding the De-Duster, into a dust collector. This is the first stage in the cleaning process.

The second stage is virtually a repetition of the first, and assures the thorough scouring of the gravel or sand passing through the machine. In the middle hopper the material is turned over and is again sent in opposite directions by a cone set in the bottom of the hopper. In falling down into the third and last hopper, the curtains of gravel are once more subjected to blasts of low-pressure air which is forced upward through a 2-way nozzle. This completes the treatment. The air laden with fines and dirt is carried into the common framed-bag dust collector, where the discarded material is graded and turned out in dry usable form.

The De-Duster can be regulated by means of the flow-control valve and the air nozzles so as to remove particles from 10 mesh down to impalpably fine dust. The shell and hoppers of the machine are built of ¼-inch plate to resist abrasion.




## ELECTRIC LIGHTS ASSIST IN TESTING BEARINGS

BY SUBSTITUTING a group of electric lights for the usual dial of a micrometer testing device, a manufacturer of bearings has succeeded in giving to the inspector a plainly visible means of gauging them. In consequence, he can test many more bearings in a given time and he can do this without the eye strain that inevitably follows the reading for any length of time of a fine scale.

Under the new system, each bearing is placed on a steel table, and a pointer from the micrometer overhead is brought in contact with its upper surface. If the dimensions of the bearing are within the prescribed limits, an amber light flashes, and the part is placed on a conveyor for transfer to the assembly room. Undersize is indicated by a red light—a signal that the bearing is not fit for use and must go to the reclaiming department. In the case of oversize, the appearance of a green light tells the inspector that that particular bearing needs further machining.

## JAPANESE TUNNEL IS YEARS IN BUILDING

STARTED more than fourteen years ago, the Tanna railroad tunnel on the Izu Peninsula of Japan probably is still a year or more from completion. To date it has cost nearly $11,000,000, and it is estimated that $1,500,000 more has to be spent. It will have a length of 25,614 feet, or about 4.8 miles, of which 2,200 feet remained to be driven last July.

A succession of difficulties has beset the workers. The core of the mountain which it penetrates was found to be cut by hundreds of water courses. The striking of some of these produced veritable geysers which flooded the tunnel and stopped work for months at a time. Sometimes the water could be grouted off; but where this was impossible, changes in the course of the line had to be made.

On several occasions earthquakes raised or lowered the floor of the tunnel as much as 6 feet. Studies reveal that Tanna Mountain is of volcanic origin, and this is borne out by the striking of zones of sand, slime, dirt and rocks. Cave-ins have been comparatively frequent, and some of them have resulted in casualties to workers.

The tunnel is designed to shorten the running time of the railroad between Kozu and Numazu by fifteen minutes.

## INDUSTRIAL LITERATURE

AN illustrated bulletin describing a new dragline bucket, known as the "Red Arch", has been issued by Bucyrus-Erie Company, South Milwaukee, Wis. This piece of equipment is made in sizes which range in capacity from ½ to 8 cubic yards.

*Steam Tables* is the title of a 38-page booklet issued by The Superheater Company, New York, N. Y. It is a handy reference book for the engineer and others interested in the generation and use of superheated steam and in associate subjects.

Briggs & Stratton Corporation, Milwaukee, Wis., has issued a folder descriptive of its new type of "Air Saver" air valve for presses and machines requiring compressed air in regulated amounts at intermittent periods. An installation instruction sheet accompanies the folder.

*Rock Drills and Sharpeners* is the title of a 32-page illustrated catalogue which consolidates in one volume essential information concerning Ingersoll-Rand equipment for drilling rock and for reconditioning drill steels. In addition to describing the various rock drills, including "Calyx" core drills, the booklet covers all accessory equipment and also contains instructions for correctly heat-treating drill steels. Copies of the catalogue, Form 4101, may be obtained from the general offices of Ingersoll-Rand Company, at 11 Broadway, New York, N. Y., or from any one of the company's numerous branch offices.

*Notes on the Orifice Meter: the Expansion Factor for Gases* is the title of a paper by Edgar Buckingham of the United States Bureau of Standards. It contains a discussion of recent experimental data which show how the expansion factor depends on the form of the meter, the ratio of downstream to upstream pressure, and the specific heat ratio of the gas. The conclusions are summarized in an empirical equation which may be used for computing the value of the expansion factor in certain cases. The price of the paper is five cents, and it may be obtained from the Superintendent of Documents, Washington, D. C.

*The Suitability of Certain Canadian Sands for Use in Sandblasting* is the title of a 41-page bulletin prepared by L. Heber Cole, R. K. Carnochan, and W. E. Brissenden and published by the Mines Branch, Canada Department of Mines, Ottawa. The pamphlet deals with sand-blast tests made under service conditions, and is comprehensive in its scope. It includes tables of analyses and of results obtained with the different sands used, as well as numerous plates showing the structure of the granules and the surfaces of the steel plates before and after sand-blasting. The bulletin contains much useful information, and may be obtained free upon application.